arV
16682

Cornell University Library
Ithaca, New York

BOUGHT WITH THE INCOME OF THE
IRVING PORTER CHURCH FUND
THE GIFT OF THE
CORNELL SOCIETY OF CIVIL ENGINEERS
AND OTHER STUDENTS OF
PROFESSOR CHURCH

1917

Cornell University Library
arV16682

A manual on explosives,

3 1924 031 442 407

olin,anx

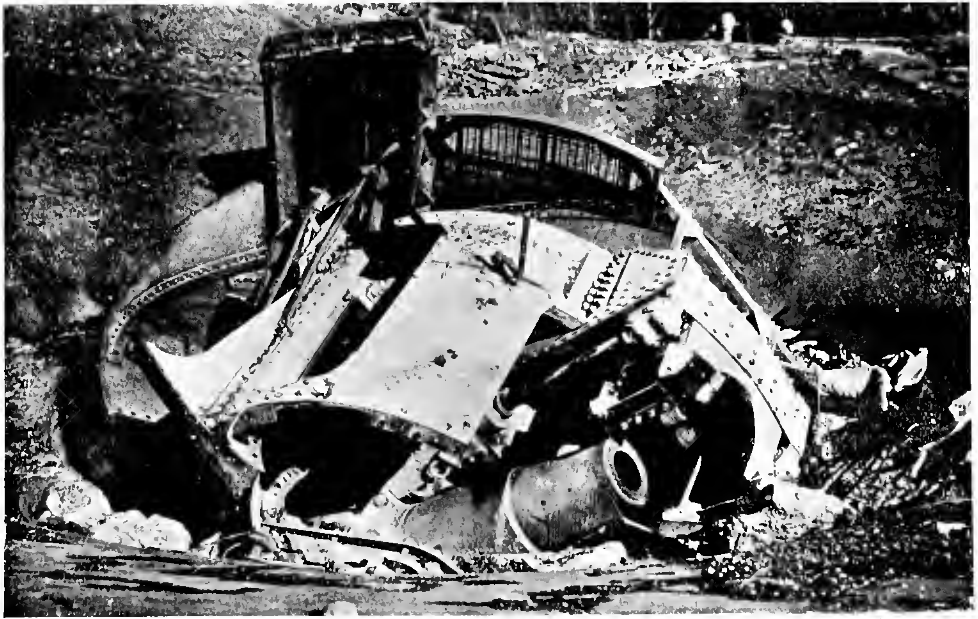
Cornell University Library

The original of this book is in
the Cornell University Library.

There are no known copyright restrictions in
the United States on the use of the text.

http://www.archive.org/details/cu31924031442407

A MANUAL ON EXPLOSIVES



Topical Press

HEAVY GUN WRECKED BY HIGH-EXPLOSIVE SHELLS AT TSINGTAU.

A MANUAL ON EXPLOSIVES

BY

ALBERT R. J. RAMSEY

AND

H. CLAUDE WESTON

ILLUSTRATED BY THE AUTHORS

SECOND EDITION (REVISED)

LONDON
GEORGE ROUTLEDGE AND SONS, LIMITED
NEW YORK: E. P. DUTTON & CO.
1917

PREFACE

In placing before the public this little Manual, the authors hope that it will supply what they believe to be a real want at the present time.

Notwithstanding the very large number of workers now engaged in the production of munitions, the importance of high explosives among which has recently been very strongly emphasized, no book has appeared which will enable the munitions worker or the interested general reader to obtain, at a low cost, a concise and intelligent understanding of the nature and manufacture of explosives. It is with the object of supplying this knowledge in a form as readable and non-technical as possible, as well as of explaining the very important part which explosives play in the sphere of modern engineering, that the following pages have been written. The authors desire to express their thanks to F. Heron Rogers, Esq., A.M.I.Mech.E., F. B. Dehn, Esq., M.Sc., Ph.D., and F. W. Bradley, Esq., A.R.C.O., for valuable assistance in the preparation of the work.

A. R. J. R.
H. C. W.

London.

PREFACE TO THE SECOND EDITION

The reception accorded to this little book by the section of the public for whom it was intended, encourages the authors to think that it has succeeded in supplying a want. Advantage has been taken of the issue of a new edition to revise the section on Cordite, so as to bring it quite up to date.

A. R. J. R.
H. C. W.

BIBLIOGRAPHY

Explosives: their Manufacture, Properties, Tests, and History. A. Marshall. 1915.

The Modern Explosives Industry. W. Barbour, M.A., B.Sc., F.I.C., in Martin's "Industrial and Manufacturing Chemistry." 1913.

Industrial Nitrogen Compounds and Explosives. Martin and Barbour.

Artillery and Explosives. Sir Andrew Noble.

Explosives. Brunswig. 1912.

Notes on Military Explosives. Weaver. 1910.

Nitro-Explosives. P. G. Sanford, F.I.C., F.C.S. 1906.

Twenty-years' Progress in Explosives. O. Guttmann. 1905.

Gunpowder and Ammunition. Col. Heime. 1904.

Smokeless Powder, Nitro-Cellulose, and the Theory of the Cellulose Molecule. Bernadon. 1901.

Handbook on Modern Explosives. M. Eissler. 1897.

Lectures on Explosives. Walke. 1897.

Manufacture of Explosives. O. Guttmann. 1895.

Guide to Explosives Act (1875). Thompson. 1906.

Industrial Poisoning. Rambousek. 1913.

LIST OF ILLUSTRATIONS

DESTRUCTION OF BIG GUN BY HIGH-EXPLOSIVE SHELLS *Frontispiece*

FIG. PAGE
1. FOURTEENTH-CENTURY BOMBARD - - - - 3
2. GUNPOWDER BREAKING-DOWN MACHINE - - 13
3. MODERN GUNCOTTON FACTORY - - - - 27
4. CENTRIFUGAL NITRATOR - - - - - 29
5. SECTION THROUGH NATHAN-THOMSON NITRATING PAN 30
6. PLAN OF FOUR NITRATING PANS - 31
7. DIAGRAMMATIC ARRANGEMENT OF ACID PLANT FOR GUNCOTTON - 32
8. PART SECTIONAL VIEW OF BEATER - - - 36
9. POACHER (SWIRLING TYPE) - - - - 37
10. MODERN NITRO-GLYCERINE FACTORY - - - 42
11. SECTION THROUGH NITRATOR-SEPARATOR - - 44
12. ,, ,, WASHING TANK - - 48
13. DYNAMITE CARTRIDGE-MAKING MACHINE - - 54
14. DIAGRAMMATIC LAYOUT OF T.N.T. PLANT - - 66
15. ,, ,, ,, PICRIC ACID PLANT - 73
16. HYDRO-EXTRACTOR - - - 76
17. DIAGRAM OF SAFETY-FUSE MAKING MACHINE - 79
18. SECTION OF HAND GRENADE - - - - 86
19. ,, ,, FLOATING CONTACT MINE - - - 87
20. SECTION THROUGH RIFLE BULLET - - - - 88
21. ,, ,, HIGH-EXPLOSIVE SHELL - - 90
22. ,, ,, AERIAL BOMB - - - 90
23. PRIMER AND CARTRIDGE IN BORE HOLE - - 94
24. PRIMER - - - - - - - - - 95
25. ELECTRIC FUSE - - - - - - 96
26. PLAN OF ROCK BLAST - - - 97
27. SECTIONAL ELEVATION OF ROCK BLAST - - - 98
28. AIR PURIFIER AND DUST TRAP - - - - 109

A MANUAL ON EXPLOSIVES

CHAPTER I

INTRODUCTION

EXPLOSIVES may be simply explained as substances, either in solid or liquid form, which by the action of heat or other cause are capable of very rapid conversion into gases, occupying a much larger space than the original substance.

The fact of certain substances possessing such properties has been known for many centuries, and there is perhaps no substance which has wrought such important changes in the world's history as Gunpowder; and yet its origin will always remain one of the mysteries of antiquity, for no one can say with certainty where, or by whom, it was first used. The invention of gunpowder is by various authorities attributed to the Chinese, the Arabs, the Hindus, and with a greater degree of certainty to several mediæval monkish alchemists, and among the many legends surrounding its origin, the fact has been fairly well established that its properties were known to the great English pioneer of science, Roger Bacon, who died in 1294, and who is, by some, claimed to be the inventor.

It is certain, however, that gunpowder as it is known to-day was in use soon after the year 1310, and the general tendency now is to regard Berchtold Schwarz, a monk of Cologne, as the inventor, although it is more probable that what Schwarz did was to adapt for use as a propellant the mixture whose explosive powers were already known, thus providing the armies of his day with the forerunners of modern artillery.

It should be remembered that many years prior to the time of Schwarz it had become the custom in warfare to hurl burning and incendiary masses by means of the great catapults formerly used for hurling stones. The fire-balls and other missiles frequently contained a mixture known as Greek Fire, which generally consisted of ingredients such as sulphur, pitch, resin, etc. The property of saltpetre of deflagrating with burning bodies having been known since very early times, it is not difficult to imagine that it might at some time have been added as a further ingredient in Greek Fire, the composition of gunpowder probably being arrived at in this way by a simple process of evolution.

It remained, however, for the German monk Schwarz to first utilize this explosive mixture as a propellant to throw a mass of stone or iron through the air in a more efficient manner than had been possible with the purely mechanical means formerly employed, such as the catapult and the crossbow.

Schwarz's invention of firearms is now generally concluded to have taken place about the year 1313, and shortly afterwards, in the reign of Edward III., we find in the accounts of the Royal Household items relating to the purchase of sulphur and saltpetre for the guns, and it is a further established fact that guns or bombards, as they were then called, were used by the English at the Battle of Creçy in the year 1346. From that time onwards, at every battle of importance that was fought, gunpowder was used with ever-increasing effect, to send death and destruction into the ranks of opposing armies.

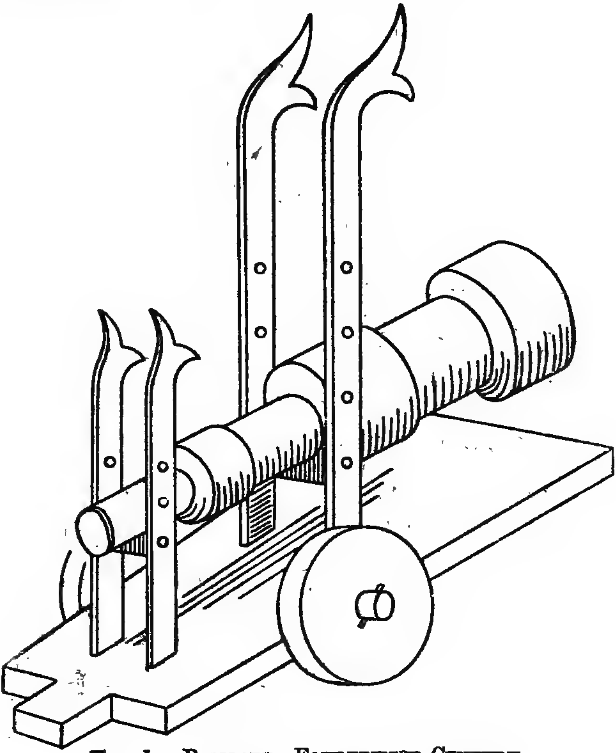


FIG. 1.—BOMBARD, FOURTEENTH CENTURY.

After this momentous innovation in warfare, the history of explosives is a blank for nearly five hundred years, during which period no new explosive was invented, although various attempts were made, especially during the latter part of the period, to add other ingredients to gunpowder with the object of increasing its explosive power, and to find substitutes for its essential ingredients, the experiments in both cases being unsuccessful.

It was not until the forward movement in chemical research that formed part of the great expansion of scientific knowledge which took place in the nineteenth century, that many other mixtures and compounds were found to possess explosive powers, in many cases far greater than those of the old black powder.

The first discovery of importance was that of the explosive powers of the various nitro-compounds, which should not be confused with the nitrates of sodium or potassium, which, under the name of Saltpetre, form an ingredient in gunpowder.

It was the discovery by Braconnot of Nancy, in the year 1832, that starch, wood fibres, and similar substances would yield easily combustible substances which he called Xyloidine, when treated with nitric acid, that led to a series of experiments and further discoveries which have resulted in the modern high explosives.

One of the most important discoveries, and one that has had most far-reaching effects, was made in the year 1845 by a chemist of Bale, named Schonbein, who found that cotton could be converted into a highly explosive body without changing its structure, by treating it with nitric acid. For some time, however, the importance of this discovery was somewhat minimized by the fact that no one knew how to purify the gun-cotton, and since the purification of the raw cotton from which it was made was not thought to be of any importance, the various experimenters were faced with the problem that the new explosive was without stability, and could not be kept unaltered for any length of time.

The invention of a process for making a stable and uniformly acting gun-cotton was due to von Lenk, and took place during the years 1847 and 1848, after a series of explosions had destroyed works where gun-cotton was manufactured in England and on the Continent. The system of purification, however, was even then imperfect, and it was not until the year 1865 that Sir Frederick Abel patented a process by which gun-cotton is thoroughly purified, reduced to powder, and pressed.

Simultaneously with the later developments in the art of manufacturing gun-cotton, a series of experiments were being carried out by an Italian chemist named Ascamio Sobrero, who, in the year 1846, had discovered Glycerine to be a body highly suitable for nitration, the resulting product being named Pyro-glycerine, which, in spite of the properties it was known to possess, remained without being utilized to any extent, except medicinally, and without further development, until, in the year 1863, Alfred Nobel of Sweden found that pyro-glycerine could be exploded by means of small gunpowder charges. Nobel introduced it as a blasting agent under the name of Nitro-glycerine, its natural state being that of a liquid; many attempts subsequently being made by Nobel and others to overcome the difficulties and dangers consequent upon handling a substance of such high explosive power in liquid form, and to produce it as a non-liquid mass.

After many experiments Nobel found that by mixing Kieselguhr (infusorial earth) with the nitro-glycerine a very plastic and absorbent product was obtained, which could easily be introduced into bore-holes. To this product Nobel gave the name of Dynamite. Originally dynamite had to be exploded by means of charges of sporting powder, but shortly afterwards E. A. Brown found that fulminate of mercury could be used with safety and certainty for exploding gun-cotton, and it was not long before this means was employed for detonating dynamite also.

The period is now reached when the discovery of new explosives took place rapidly, the next advance being again due to Nobel, who, in the year 1878, by combining di-nitro-cellulose with nitro-glycerine invented Blasting Gelatine, which has a much stronger effect than dynamite. Another modern explosive, Picric Acid, has been known commercially for more than 140 years, but it was not until the year 1867 that Borlinetto found that a mixture of picric acid, sodium nitrate, and potassium chromate, was suitable for a blasting powder.

Picric acid in a compressed and molten state, in combination with collodion, for filling shells, was patented in 1887 by Eugène Turpin, and is known as Melinite, the method of detonating molten picric acid by a primer of dried gun-cotton being discovered in Italy in the same year.

Among the experiments which were made to produce gunpowder from nitro-compounds, it is to be noted that the well-known Schultz Powder was first made by E. Schultz in 1864 from nitrated wood, and is still extensively used for sporting purposes. The E.C. Sporting Powder was first made in 1882 by W. F. Reid, by granulating gun-cotton and dipping it in ether alcohol.

An entirely new departure was made by the celebrated French chemist, Veille, in 1886, who, by dissolving gun-cotton in sulphuric ether mixed with picric acid, devised a smokeless gunpowder, that is, one developing little or no smoke on combustion. This invention was followed rapidly by many other smokeless powders, one of which, Ballistite, was patented in 1888 by Nobel, who conceived the idea of reducing the rate of combustion of his blasting gelatine by increasing the percentage of gun-cotton, to enable it to be used for military purposes.

Sir Frederick Abel, who has already been mentioned in connection with the purification of gun-cotton, invented, in conjunction with Sir James Dewar, the explosive known as Cordite, which consists of a combination of highly nitrated cellulose and nitro-glycerine dissolved in acetone.

The use of the newly discovered high-explosive compounds has now become so general, both for military and blasting purposes, that the old black powder which stood for centuries as the only explosive has now been practically superseded, and bids fair to shortly become a matter of history only.

CHAPTER II

EXPLOSIVE MIXTURES: (1) GUNPOWDER

GUNPOWDER belongs to that class of explosives which are mechanical mixtures, the ingredients being simply ground together without any chemical action taking place.

The three ingredients forming the mixture are saltpetre, sulphur, and charcoal, their proportions in gunpowder having varied to a very great extent during its six hundred odd years of history. In its earliest form there is every reason to believe that the three ingredients mentioned were used in substantially equal quantities, but practical experience must have soon shown that an excess of charcoal merely produced clouds of unnecessary smoke, and sooty deposits in the firearms. It will, therefore, readily be seen why, early in its history, the proportion of saltpetre increased whilst that of charcoal decreased, until at the present day ordinary black powder is made up in the following manner:

	Per Cent.
Saltpetre	75
Sulphur	10
Charcoal	15

A slight modification of these figures is found in the composition of slow-burning prismatic powders, whose proportions are somewhat as follows:

	Per Cent.
Saltpetre	79
Sulphur	3
Charcoal	18

As regards the two latter substances, no change has, of course, taken place throughout the ages, but in regard to saltpetre the case is different. This ingredient in the mixture was supplied for many years by potassium nitrate (KNO_3), but during the experiments which were made towards the close of the eighteenth century to find reliable substitutes for the substances used in the manufacture of gunpowder, it was found that sodium nitrate or nitre ($NaNO_3$) possessed almost equal properties, and since that time it has been increasingly used, especially in the cheaper powders, its discovery in large deposits in Chili tending to increase its use in this respect.

When, in exceptional circumstances, the sensitiveness of saltpetre to moisture is objectionable, barium nitrate is used, and can be conveniently made from barium carbonate treated with dilute nitric acid, or by decomposing barium chloride by sodium nitrate.

The function of the saltpetre ingredient is to supply the oxygen necessary for combustion, whilst the sulphur, besides possessing combustible properties, lowers the temperature of ignition.

The charcoal used is preferably that obtained by destructive distillation from dog-wood, alder or willow, and for some special makes of powder carefully selected straw is used instead of wood; but it should be understood that charcoal obtained from many other substances can be, and is, used. Charcoal obtained from the substances above specified is now almost exclusively used, as, after exhaustive tests, it has been found to be the most readily ignited, the most quickly burnt, whilst giving at the same time the least quantity of ash. According to one method, the charring is carried out in a cast-iron cylinder bricked into a furnace and provided with a tightly-fitting cover. The wood is packed in wrought-iron cylinders about 2 feet 4 inches in diameter and 3 feet 4 inches long. These cylinders are closed with lids and placed in the stills, and after the charring operation are withdrawn and taken on trucks to a cooling-room. It is necessary that the cylinders should be kept tightly closed during the cooling operation, as otherwise the charcoal, being in a highly heated state, is liable to catch fire.

Before sulphur can be used in the manufacture of gunpowder it must be purified, and the following method of accomplishing this is an up-to-date example of several that are commonly employed.

Crude sulphur is heated in an iron still, and as vapours come off they are led into a large arched chamber wherein sulphur is deposited in the form of flowers of sulphur. Air escapes from this chamber through a water seal. After about three hours of this action the vapour changes colour from yellow to dark violet, and communication is then cut off between the still and the arched chamber and opened between the still and a collecting vessel. Cold water is allowed to run through the pipe connecting the two latter, and in this pipe sulphur condenses and runs into the collector as a clear yellow liquid. It is subsequently cooled, and the flowers of sulphur are redistilled.

The third ingredient in gunpowder, saltpetre, has also to be refined before it can be used. Again several processes are commonly used, the one herein described being that most commonly in use in this country. In carrying out this process the saltpetre is placed in copper boilers about 40 cwt., at the time made up of about 25 cwt. of crude saltpetre, 5 cwt. of crystals from evaporated mother liquors, 5 cwt. of crystals left in the crystallizing pans, and 280 gallons of water from washing the purified saltpetre, of which it contains about 5 cwt. The solution boils after about two hours' heating, the temperature then being about 230° F. Cold water is added periodically to promote the separation of scum, the formation of which ceases after about half an hour. The liquor, after another short period of boiling, is allowed to cool until its temperature is about 220° F., when it is pumped into the filters. Passing through these the liquor runs into crystallizing pans to the depth of about 6 inches, being kept constantly in motion by stirring. The crystals formed are drawn up on the side and thrown on to draining shelves, from which they are raked into washing-vats. It is washed in three different waters and is left overnight in the washing-vats, after which it is taken out and stored for three days. At the end of this time only 3 to 5 per cent. of moisture remains, and the saltpetre can be used for the manufacture of powder without further drying.

Points of great importance in the manufacture of black powder are that the ingredients should be pulverized as finely as possible, that they should be intimately mixed, and that the resulting powder should have a high density. Until recent times the pulverizing, mixing and caking were performed in one operation, but as many explosions occurred each operation is now carried out separately.

(*a*) PULVERIZING.—There are many known methods of carrying out this operation, in some of which the ingredients are pulverized separately in drums or in mills of the edge runner type, whilst the latter are frequently used, especially in Great Britain, for pulverizing all three together.

(*b*) MIXING OR INCORPORATING.—The material is spread finely over a bed and kept moistened with distilled water to prevent dust arising. The mills employed for this part of the process are generally similar to the pulverizing mills already described, and during this operation the mixture becomes caked. Mixing drums, are, however, largely employed for sporting powders.

(*c*) PRESSING.—Before pressing can take place the powder must be again "broken." First of all it is broken into large pieces by wooden mallets, and is subsequently treated in a "breaking down" machine (Fig. 2). This consists, briefly, of a hopper from which the pieces of cake are transferred by an endless conveyor to a pair of grooved brass rollers, which crush it to a fine flour which falls into a box beneath.

Density being the property which has the greatest effect on the general character of gunpowder, it is essential that it should be as high as possible, and to attain this very powerful presses, generally hydraulic, are used. In charging a press a plate is first put on a carriage and is surrounded by a wooden frame deeper than the thickness of the plate. The powder is put in this frame, smoothed off, and a second plate placed on the top of it. This operation is repeated until, when a column of powder cake and pressing plates is built up, the carriage is run on to the table of the press and the pressure applied for about thirty to forty minutes.

(*d*) Granulating.—Formerly black powder was used in the form of dust, and the precise date when grain powder began to be used is unknown.

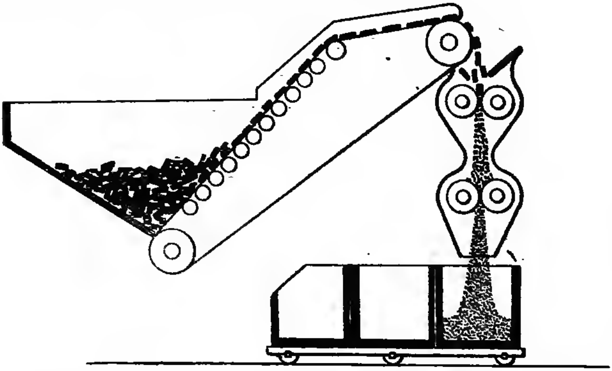


Fig. 2.—Diagram of Breaking-Down Machine for Gunpowder.

After caking, the powder is again broken up and passed through sieves, which may be mechanically agitated, to separate the dust from the grains, and the latter into various grades according to size.

(*e*) Glazing.—The object of this is not so much to make the powder smooth, but to break off sharp points and fill up pores in the grain, the powder being thereby rendered much less sensitive to atmospheric moisture, and less likely to deposit dust. The glazing takes place in drums rotating at about nine revolutions per minute.

(*f*) Drying.—Many methods are in use for performing this operation also, and one largely in use in this country is that in which the powder is placed in wooden trays mounted in frames containing eight trays one above another. Steam pipes are arranged at the lower part of the frames and the maximum temperatures allowed are as follows:

Granulated powder	..	..	125° F.
Cubical ,,	..	..	140° F.
Prismatic ,,	..	..	95° F.

Granulated powder occupies from six to twelve hours in drying, but including the heating up and the cooling the operation lasts about a day.

(*g*) DUSTING.—After the operations above described it is necessary to remove the dust which has formed. This is generally done in cylindrical sieves about 8 feet long and 2½ feet in diameter, enclosed in a box, and covered with fine brass wire or silk gauze as used in flour dressing.

This operation lasts about three hours, and frequently a little blacklead is added to increase the gloss of the powder, and by increasing the density of the surface renders the powder less hygroscopic.

The density of the final product varies from 1·5 to 1·85, depending upon the amount of pressure which has been used. Good gunpowder consists of hard angular grains which do not soil the fingers and which are a uniform dark grey in colour, bluish or jet-black tints denoting an excess of water or charcoal respectively. When exposed to the air it should not absorb more than 1·5 per cent. of moisture.

Gunpowder can be detonated by a blow between hard materials, or by contact with hot or burning bodies at a temperature of about 300° C. When ignited in the open air small quantities simply burn, but, on the other hand, large quantities explode in the same manner as in a confined space, the products of the explosion being partly solid and partly gaseous, the latter occupying about three hundred times the volume of the gunpowder.

Owing to the great number of years during which gunpowder was the most important explosive, many different machines were devised for performing each operation described herein, but the space available has only permitted a brief description in each case of one typically modern piece of apparatus.

EXPLOSIVE MIXTURES: (2) NITRATE EXPLOSIVES (*a*)

Of the many explosives which have been invented containing as an ingredient the nitrate of ammonium, potassium, or sodium, space will only permit the description of a few of the more important. Some of these explosives have been invented solely with the object of providing a cheaper substitute for gunpowder, which, strictly, should be included under this heading, although its importance has necessitated its treatment in a separate section. Others, again, have been evolved with the object of attaining a powder the explosion of which is unaccompanied by either flame or smoke, and to meet various other requirements of sporting and blasting powders.

SCHULTZE GUNPOWDER.—The composition of this well-known powder is as follows:

	Per Cent.
Nitro-ligroin	62·1
Potassium nitrate (KNO_3)	1·8
Barium ,, $Ba(NO_3)_2$	26·1
Vaseline	4·9
Starch	3·5
Volatile constituent	1·0

The process employed in mixing these ingredients consists in first macerating soft timber, which is then purified of all resinous and fatty matter, until pure, finely divided cellulose remains. After drying, this is nitrated by heating with acids, purified, ground, and the vaseline added as a waterproofing agent.

E.C. Powders are also known as rifle guncotton, and have the following composition:

	Per Cent.
Nitro-cellulose	79·0
Potassium nitrate	4·5
Barium ,, ...	7·5
Camphor	4·1
Wood meal	3·8
Volatile matter	1·1

These powders are made in two divisions, the sporting powder being coloured with aurine (free from mineral acid) dissolved in ether alcohol and benzoline; and rifle powder, coloured with picric acid (free from mineral acid), dissolved in the same solvents. The two powders consist of small round granules coloured respectively orange and yellow.

Roburite consists of 86 per cent. of ammonium nitrate (NH_4NO_3) and 14 per cent. of chlordinitrobenzol, and belongs to that class of explosives whose detonation under confinement is not accompanied by a flame. It is much used in coal mines, as it is claimed that the gases resulting from the explosion will not ignite fire-damp or coal-dust.

Securite is very similar in properties to Roburite. It consists of a mixture of 26 per cent. of metadinitrobenzol and 74 per cent. of ammonium nitrate (NH_4NO_3), the latter being sometimes replaced by potassium nitrate (KNO_3). It is a yellow powder, with the odour of nitro-benzol. Securite does not seem to explode by friction, pressure, a blow, fire or electricity, but explodes under the influence of a powerful detonation, the explosion being flameless. It is principally used in blasting, and has a rending rather than a pulverizing action.

BELLITE is similar in many respects, especially properties, to Securite, and contains the same ingredients but in different proportions, there being five parts of potassium nitrate to every part of metadinitro-benzol.

TONITE is a blasting explosive, made in three qualities, and which is essentially a mixture of gun-cotton and a nitrate, preferably that of potassium or barium.

The gun-cotton used is manufactured in the manner described hereinafter in Chapter III., except that whilst in the moist state the fibres are macerated or disintegrated between crushing rollers, and afterwards intimately mixed up between edge runners with about the same weight of barium nitrate. The substance thus formed is next compressed into candle-shaped cartridges, formed with a recess at one end for the insertion of a fulminate of mercury detonator, and covered with paraffin paper.

Tonite possesses the advantage that if wetted by accident it can be safely dried in the sun or in a warm atmosphere, and it is a safe explosive for use in mines, as the large proportion of oxygen present in barium nitrate renders its detonation perfect in that no noxious gases are present after it has been exploded.

The powder known as Tonite No. 1 is made up of from fifty to fifty-two parts of gun-cotton and from fifty to fifty-seven parts of barium nitrate.

It is known as White No. 1, and is principally used for blasting hard stone where a shattering effect is required.

Tonite No. 2, or Black No. 2, as it is called on account of the small percentage of charcoal which it contains in addition to the ingredients of No. 1, is used in blasting softer stone, its explosion being slower and only producing fractures.

Tonite No. 3 is principally used in blasting coal, and is made up in substantially the following proportions:

	Per Cent.
Gun-cotton	18–20
Barium nitrate	67–70
Dinitro-benzol	11–31
Moisture	·5–1

The composition of this mixture is sometimes varied to include a small proportion of sodium nitrate or chalk.

Faversham Powder is very similar to Roburite, but with the object of making the powder absolutely flameless it is coated with a small quantity of Trench's Fire Extinguishing Compound. The latter consists of sawdust impregnated with certain chemical substances, and has the appearance of dirty salt. The actual composition of the explosive is as follows:

	Per Cent.
Ammonium nitrate	85
Dinitro-benzol	10
Trench's Compound	5

It should be mentioned, however, that trinitro-toluol is sometimes substituted for the dinitro-benzol in substantially the same proportions.

Favier Explosives.—Owing to the danger of explosions of fire-damp and dust in mines, it is necessary to use mixtures having a low temperature of explosion, and to this end the properties of ammonium nitrate (NH_4NO_3) have been utilized. In 1884 and 1885 Favier took out patents for mixtures of ammonium nitrate with mononitro-naphthalene, or dinitro-naphthalene, paraffin, and resin.

In the manufacture of these explosives, ammonium nitrate is dried and ground in a mill, the pan of which is heated. The nitro-naphthalene is then added, and the incorporation carried on for an hour or two in a warm, dry room. After cooling, the mass is ground to powder, and formed under pressure into cartridges. The cartridges are coated with metal foil or paper rendered waterproof by dipping in a bath of paraffin wax. This waterproofing is necessary owing to the hygroscopic nature of ammonium nitrate. The composition of the Favier explosives has varied from time to time, but the following is typical:

	Per Cent.
Ammonium nitrate	88
Dinitro-naphthalene	12

Many other blasting explosives are manufactured, consisting of mixtures of ammonium nitrate, various other nitrates and nitro-benzene compounds, but those already described are fairly representative.

NITRATE EXPLOSIVES (*b*)

Under this heading will be found a selection from the large number of explosives which, besides containing a nitrate compound, also include nitro-glycerine as an ingredient. As will be understood from Chapter I., nitro-glycerine is naturally a liquid, and to render it solid and safe to handle an absorbent has to be used, and on the following pages a number of explosive powders are described in which explosive absorbents are employed instead of the inactive kieselguhr used by Nobel, the inventor of dynamite. The object of the change is to produce a substance which will decompose as completely as possible into carbonic acid and water.

Nitro-glycerine explosives require careful attention, as they are apt to decompose spontaneously, and any indication of acid fumes, or any tinge of green in them, should be followed by their prompt destruction, with suitable precautions.

Forcite is a mixture of nitro-glycerine with cellulose, the latter being gelatinized by heating in water under pressure, and consists of the following proportions:

	Per Cent.
Nitro-glycerine	49·0
Gun-cotton	1·0
Sulphur	1·5
Tar	10·0
Sodium nitrate	38·0
Wood pulp	0·5

In manufacturing Forcite, thin blasting gelatine with gun-cotton is incorporated with a mixture of sodium nitrate coated with molten sulphur and wood tar. The wood pulp is added to counteract the sticky qualities of the tar, whilst the latter is used to prevent the blasting gelatine from soaking into the base, which is used as a carrier rather than an absorbent.

Forcite combines the properties of exploding when confined in a drill-hole, and of burning without explosion in the air. Water has no action upon it, and the nitro-glycerine is so firmly united with other materials that it cannot be separated by sulphuric ether or alcohol.

Giant Powder is the American form of dynamite, and contains a smaller proportion of nitro-glycerine, its actual composition being as follows:

	Per Cent.
Nitro-glycerine	40
Sodium nitrate	40
Resin	6
Sulphur	6
Kieselguhr	8

Other nitrates may be used, and other carbonaceous substances substituted for the resin.

Ammonium Dynamite, also known as Ammonia Powder, surpasses ordinary dynamite in point of power as a blasting agent, when freshly prepared, but it has no keeping qualities, owing to the hygroscopic nature of its chief ingredient, ammonium nitrate. Its actual composition is as follows:

	Per Cent.
Ammonium nitrate (NH_4NO_3)	75
Paraffin	4
Charcoal	3
Nitro-glycerine	18

Carbonite is an explosive in which a small proportion of nitro-glycerine is mixed with a number of other substances in the following proportions:

	Per Cent.
Nitro-glycerine	17·76
Nitro-benzene	1·70
Soda	·42
Potassium nitrate	34·22
Barium ,,	9·70

	Per Cent.
Cellulose	1·55
Cane sugar	34·27
Moisture	·36

VULCAN POWDER consists of a mixture in the following proportions:

	Per Cent.
Sodium nitrate	52·5
Nitro-glycerine	30·0
Sulphur	7·0
Charcoal	10·5

VIGORITE is similar to the above, but contains no sulphur. It is made in the following proportions:

	Per Cent.
Sodium nitrate	60
Nitro-glycerine	30
Charcoal	5
Sawdust	5

RENDROCK, as its name implies, is specially designed for blasting purposes, and its composition is as follows:

	Per Cent.
Potassium nitrate	40
Nitro-glycerine	40
Wood pulp	13
Paraffin and pitch	7

A number of other explosives which contain nitro-glycerine in large proportions are described in Chapter III, as they resemble dynamite more than the nitrate mixtures.

EXPLOSIVE MIXTURES: (3) CHLORATE EXPLOSIVES

Among the many powders now in use for blasting, some of the most effective are those which utilize the powerful oxidizing properties of the chlorates of potassium and ammonium. Besides being used for blasting, they are much in demand for percussion caps, and although they have greatly increased power and violence over many other explosives, they possess, on the other hand, greater sensitiveness, unless made on the principle of the Sprengel explosives, in which the oxidizing and combustible agents are kept entirely separate until immediately before explosion, a good example of a Sprengel explosive being—

RACK-A-ROCK, which consists of compressed cartridges of potassium chlorate enclosed in small bags of cotton or other cloth. The cartridges are suspended in a wire basket from a spring balance and dipped into a pail containing mononitro-benzene, the completion of the absorption of the proper amount of fluid being shown by the spring balance. The proportions necessary for perfect detonation are stated to be:

	Per Cent.
Potassium chlorate ($KClO_3$)	79
Mononitro-benzene	21

CHEDDITE.—In this explosive the sensitiveness of potassium chlorate is reduced by coating it with an oily material thickened with a nitro-hydrocarbon. The composition of Cheddite varies within certain limits, according to whether what is known as Cheddite 41 or Cheddite 60 is being manufactured. The former explodes comparatively slowly, and is used where it is only necessary to split rocks, whilst the latter is more violent in its action and has a shattering effect.

Cheddite is made approximately in the following proportions:

	Per Cent.
Potassium chlorate	80·0
Castor oil	5·8
Mononitro-naphthalene	12·13

In manufacture, the mononitro-naphthalene is dissolved in castor oil at a temperature of 60° or 70° C. The potassium chlorate, in a finely powdered state, is next added, and the mixture stirred with a wooden rod for about ten minutes. It is then removed to trays and mixed while half cold to secure a granular condition, for a further period of ten minutes, after which it is sifted and compressed into cartridges. Cheddite is a yellowish material of fine grain, plastic and easily compressed.

STEELITE consists essentially of potassium chlorate enveloped in oxidized resin, and is manufactured by mixing nine parts of ground colophony with one part of starch, and adding nitric acid. The result of this operation is the formation of an oxidized, yellow, amorphous mass, floating on the surface of the acid, which is drawn off and the mass broken, washed in water, dried and ground. The potassium chlorate is next added and the whole ground in a drum provided with balls of lignum vitæ, after which it is spread on a zinc sheet, sprinkled with methyl-alcohol, and raked constantly to prevent it forming into a paste or dough, until dry.

PETROFRACTEUR is another chlorate explosive characterized by the addition of saltpetre. It is made in the following proportions:

	Per Cent.
Potassium chlorate	67
Potassium nitrate	20
Nitro-benzene	10
Antimony sulphide	3

Potassium perchlorate ($KClO_4$) is a much more stable and less sensitive substance than potassium chlorate, and one of the principal explosives of which it is an ingredient is:

PERMONITE, with a composition approximately as follows:

	Per Cent.
Potassium perchlorate	31–34
Nitro-glycerine	3–4
Collodion cotton	·5–1
Ammonium nitrate	39–43
Trinitro-toluene	11–13
Starch	5–9
Wood meal	1·5–3·5
Moisture	0–2·5

Another useful member of the chlorate group is ammonium perchlorate, the high proportion of oxygen in which constitutes a distinct advantage. It is, however, somewhat difficult to explode, and the explosion is often incomplete.

The following are two of the principal explosives in which it is used as an ingredient:

YONCKITE—

	Per Cent.
Ammonium perchlorate	25
Ammonium nitrate	30
Sodium ,,	15
Trinitro-toluene	10
Salt	20

BLASTINE is an explosive which has recently come into very wide use, and is composed of ammonium perchlorate, salt, dinitro-toluene, and paraffin wax.

CHAPTER III

NITRIC ESTERS: (1) GUN-COTTON

THE discovery of the effectiveness of nitrated cellulose as an explosive, and its subsequent development into one of useful stability, has already been described in Chapter I., and the present chapter will, therefore, be devoted to a description of some of the modern methods according to which it is manufactured.

Gun-cotton is the hexanitrate of cellulose, having the formula $C_{12}H_{14}O_4(NO_3)_6$, and is the final product of the nitration of cotton, but less highly nitrated forms of cellulose are also used as explosives and for other purposes, the most common and useful of these being known as collodion-cotton. Many other forms of cellulose have also been nitrated for use as explosives, notably wood pulp and paper and other fibrous forms of cellulose, and even sawdust, all of which, however, have gradually been discarded in favour of cotton, although nitrated paper is still largely used in the manufacture of celluloid, which is simply nitro-cellulose gelatinized by being dissolved in a suitable solvent and rendered inexplosive by the addition of a large percentage of camphor.

In the manufacture of gun-cotton, cotton waste, of the kind used for cleaning machinery, is first treated with alkali to remove the oil and fatty matters. It is then picked by hand to remove

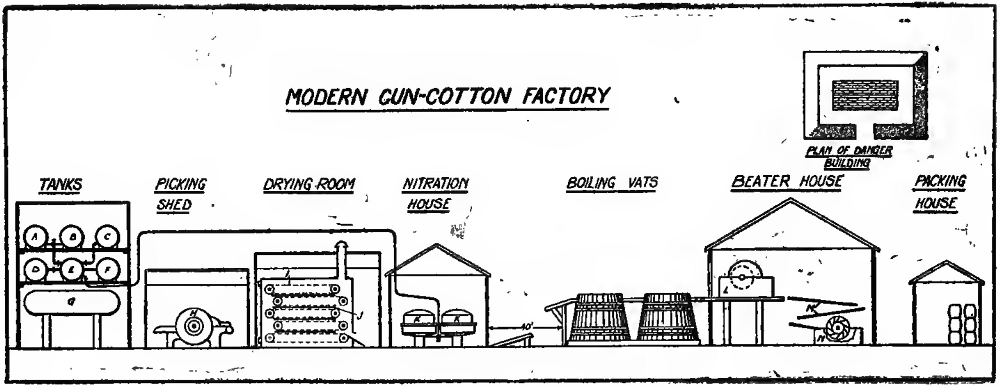


FIG. 3.

A, Sulphuric acid.
B, Sulphuric acid.
C, Nitric acid.
D, Strong waste acid.
E, Mixed acids.
F, Oleum.
G, Water.
H, Teasing machine.
I, Endless belts.
J, Steam trays.
K, Nitration pans.
L, Beater.
M, Sand trays.
N, Poacher.

solid foreign matter, and subsequently passed to a teaser or similar machine to open up and cut the material, to render it suitable for ready immersion in acid, this part of the process needing no further description, being common to all processes requiring the purification of raw cotton or other fibre.

In order that the succession of operations necessary to produce the finished product, and that the arrangement of a gun-cotton plant may be clearly understood, reference will be made to Fig. 3, which shows the lay-out of a model plant. It is to be noted that the various stages in the operation should be arranged to take place in buildings permitting strict continuity in the operations, and giving the least danger in carrying from one place to another.

After preparation by picking and teasing as above described, the cotton is dried in any suitable manner for about three-quarters of an hour, during which time it is deprived of all but ½ per cent. of its moisture. Following this treatment the cotton is allowed to stand for about eight or nine hours until quite cold, moisture being again absorbed to the extent of another ½ per cent. The next step in the process is that of nitration, prior to which the cotton is weighed into lots of 21 to 25 lbs., according to the process employed, which may be either what is termed the Centrifugal Process or the Displacement Process.

According to the first method a centrifugal is employed, the nature of which will be seen by reference to Fig. 4, and which is first filled with acid; then cotton is immersed a little at a time, until the proportion is one part of cotton to fifty

The acid employed for the nitration process consists of a mixture of nitric acid and sulphuric acid in the proportion of one part to three, the latter acid being necessary to absorb the water set free during nitration, which would otherwise dilute the nitric acid and thus render it incapable of fully nitrating the cotton. The lid is then shut down, and nitration proceeds for a quarter to three-quarters of an hour according to the variety of gun-cotton desired. The acid is now allowed to drain away through a cock in the base of apparatus to the waste acid tank, after which the centrifugal is rotated slowly at first but afterwards with considerable speed, until the proportion of free acid mixed with the cotton is greatly reduced. After the centrifugal is stopped, the nitro-cotton is

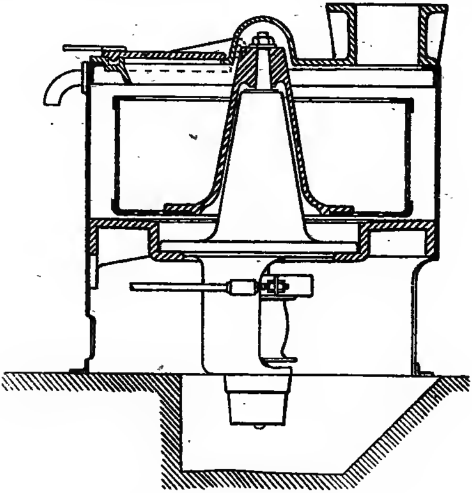


FIG. 4.—SECTION OF ACID CENTRIFUGAL.

removed with iron or aluminium tongs to tanks for immersion in running water. The fumes given off during the introduction and removal of the cotton are drawn off through an earthenware pipe by a stoneware fan.

The second method of nitration, that known as the Nathan-Thomson Displacement Process, is the method now in more general use, having been employed at the Royal Gunpowder Factory at Waltham Abbey, since August, 1905, and at other important explosives factories.

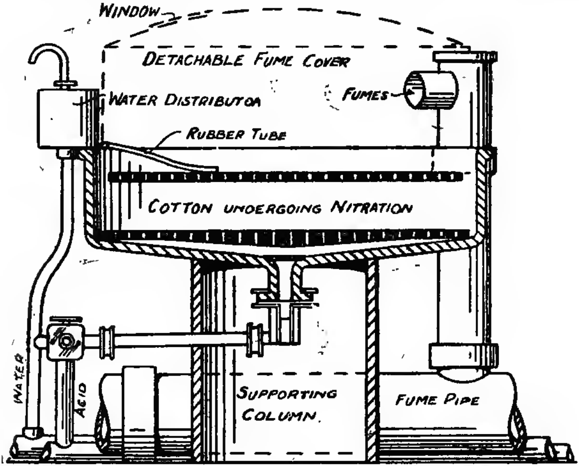


FIG. 5.—SECTION THROUGH STONEWARE NITRATING PAN FOR GUN-COTTON.

It is carried out in earthenware pans, a section of one being shown in Fig. 5, whilst Fig. 6 is a plan view of four pans, which number is generally grouped into one operative unit. Each pan is covered by an aluminium fume hood connected to an exhaust fan.

Each pan is made 3 feet 6 inches in diameter and 10 inches deep, with a fall of 2 inches towards the central outlet opening, which is ¾ inch in diameter, the four pans being connected by lead pipes, and also connected to the nitrating acids pipe, and to pipes for carrying off strong and weak waste acid and waste water.

For a ready understanding of the manner in which the acids are stored and led to and from the nitration house in a plant with up-to-date equipment, the reader is referred to Fig. 7, which indicates diagrammatically the flow of the acids from start to finish of the nitrating operation.

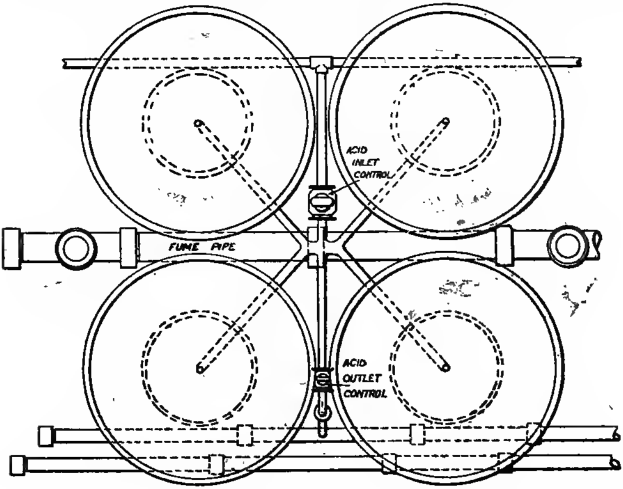


Fig. 6.—Plan of Four Nitration Pans.

Most explosives factories at the present day manufacture their own nitric acid, the method generally followed being by the action of sulphuric acid on sodium nitrate in retorts under the influence of heat. The acid produced in this way is passed

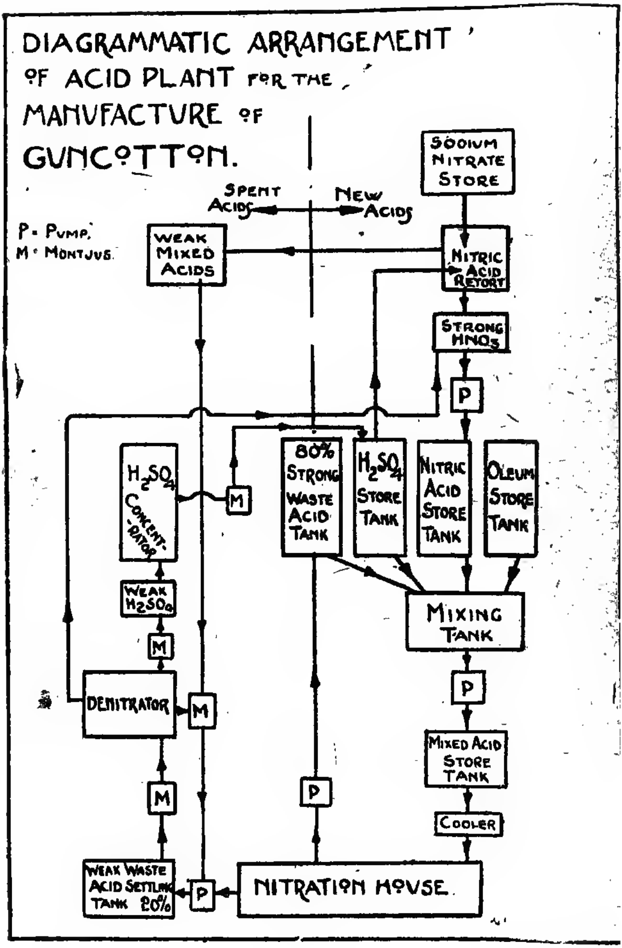

DIAGRAMMATIC ARRANGEMENT OF ACID PLANT FOR THE MANUFACTURE OF GUNCOTTON.
P = PUMP.
M = MONTJUS.
SPENT ACIDS
NEW ACIDS
SODIUM NITRATE STORE
WEAK MIXED ACIDS
NITRIC ACID RETORT
STRONG HNO3
P
H2SO4 CONCENT-RATOR
M
80% STRONG WASTE ACID TANK
H2SO4 STORE TANK
NITRIC ACID STORE TANK
OLEUM STORE TANK
WEAK H2SO4
M
MIXING TANK
DENITRATOR
M
P
MIXED ACID STORE TANK
M
P
COOLER
WEAK WASTE ACID SETTLING TANK 20%
P
NITRATION HOUSE.

Fig. 7.

to a cooling tank as indicated, from which it is drawn off by a pump to the nitric acid tank, a second pump being provided to force the mixed acids into storage tanks and through a cooler to the nitration pans.

The mixed acids drawn off from the nitration pans are passed off in two directions, the strong waste acids to a storage tank to be used over again in the process, without further treatment, whilst the weak waste acids are separated in a denitrator (occupying a separate building as shown in Fig. 10). The denitrator consists of a stone tower filled with pieces of broken stone and glass, the nitric acid passing off under the influence of heat, in the form of fumes which are cooled and condensed in stone towers and earthenware bottles, the sulphuric acid passing off to the concentrator. The nitric acid recovered, passes directly to the same strong nitric acid tank, which receives the fresh product from the retorts. The sulphuric acid separated is, of course, much diluted by the water set free during the nitration process, and it is necessary, therefore, that the acid should be freed from this water before being used again. A suitable apparatus for reconcentrating the sulphuric acid also requires a separate building, and a form largely employed consists of a number of heated trays arranged in the form of a cascade, down which the acid passes whilst giving off water vapour, and is drawn off at the bottom and passed directly to the sulphuric acid store tank which feeds the mixing tank, which contains acids in the following proportions:

	Per Cent.
Sulphuric acid	70·5
Nitric ,, ...	21·0
Nitrous ,, ...	·6
Water	7·9

This mixture is warmed during the winter, and cooled in summer, in order that nitration may take place always at an even temperature.

The composition and treatment of the acids being now understood, the manner in which they are applied to the cotton will now be described.

The perforated plate in Fig. 5 is first placed in position and the mixed acid run in, the shape of the pan being such that 600 lbs. of acid is above the perforated plate and 50 lbs. below. Next, 20 lbs. of cotton is introduced in small quantities at a time, aluminium dipping forks being generally employed for this purpose.

The upper perforated plate in the diagram is next fitted in segments on top of the cotton, and the aluminium fume hood, in which, during the introduction of acid, fumes collect to be drawn off through the fume pipe, is removed, and a film of water at a temperature of 5° to 8° C. is run on to the perforated plate, and effectually prevents the escape of acid fumes.

The nitration of the cotton by this process lasts two and a half hours, and at the end of this time the waste acid is run off at the rate of 17 lbs. a minute, and water run on to the perforated plates in equivalent quantities. In this manner the whole of the acid is displaced in three and a half hours, a further hour being occupied by the water draining through the cotton, which is then ready for boiling.

The Nathan-Thomson process of nitration has been described at some length on account of the fact that, as already explained, it is now most generally used, and possesses the following advantages over the first method described:

1. A considerable number of operations are superseded.

2. On account of No. 1 the work is less laborious, and a saving in labour is effected.
3. The fumes given off are far less in quantity.
4. A saving in power is effected, as there are no rotating parts.
5. The pans being of earthenware are far more lasting.
6. The product obtained is a more stable cotton containing less mineral matter, and the weight of gun-cotton produced is 1·7 lbs. for each 1 lb. of raw cotton.

After nitration the nitro-cotton is boiled to remove all traces of acid, as any free acid allowed to remain would give rise to a considerable amount of heat if mixed with water, with the result that the gun-cotton would become decomposed and fired. The boiling vats are indicated in Fig. 3, and are generally made of wood about 6 feet high and between 8 and 10 feet in diameter at the base, containing a steam-heated coil, and on being removed from these, the gun-cotton passes to beaters, which reduce it to the very fine state of subdivision necessary for its subsequent transformation into a compressed mass. The beater or hollander employed is similar to those employed in the manufacture of paper, and consists, as shown in Fig. 8, of a revolving trimming-knife, beneath which is a box of knife edges, whilst a cover above the trough, in which the revolving knife operates, prevents the mass being cast out while in motion. From the beaters the reduced material is passed to a poacher, which is also similar to the device of the same name in use by paper-makers, and comprises an oval tank having a paddle-wheel mounted for rotation therein, to keep the material treated in a state of constant agitation. By its means the gun-cotton is first drained of all the water in which it has been pulped, and subsequently subjected for some hours to a thorough washing and agitation, samples being periodically withdrawn and tested for purity.

A more recent form of poacher is shown in Fig. 9, in which the pulped gun-cotton is introduced through a pipe, the inlet end of which is obliquely formed, so that a swirling motion of the pulp is produced within the casing.

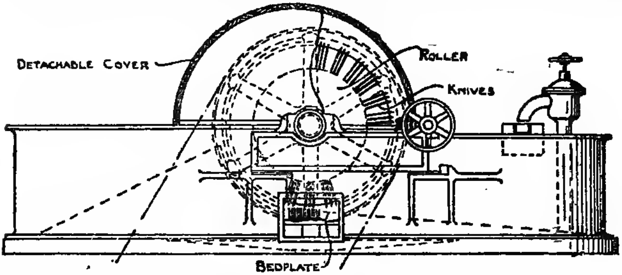


Fig. 8.—Part Sectional Elevation of Gun-cotton Beater.

Before poaching, the pulp is run along sand-troughs, in the bottoms of which are laid strips of flannel, a grit trap being arranged in the flow so as to intercept and collect particles of foreign matter floating in the mass, which is then passed through a magnetic separator to withdraw any small particles of iron which may be mixed with the gun-cotton. These devices may conveniently be situated in the same building with the beaters and the poacher. After treatment by the latter, the gun-cotton is moulded and packed.

For storage of the finished product magazines are necessary, which must be situated about 100 yards from the manufacturing plant. One of these magazines is shown in plan in Fig. 3, and consists of an ordinary building surrounded by earthworks corresponding in height to the building, and several feet thick.

After treatment in the manner above described, the cotton shows no outward appearance of change in spite of the important chemical changes which have taken place in its nature. Although unaltered in appearance, however, it is somewhat harsher to the touch, and is considerably heavier than the raw cotton, each pound of the latter treated yielding, as already described, about 1·7 lbs. of gun-cotton in the finished state.

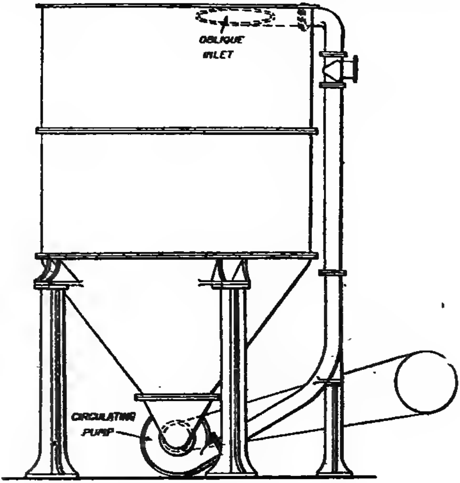


Fig. 9.—Poacher (Swirling Type).

When gun-cotton is in a wet state, there is practically no danger of explosion, the addition of as little as 3 per cent. of water rendering detonation by the ordinary means very uncertain. It has been found, however, that gun-cotton containing as much as 17 per cent. of water is comparatively easy to detonate with charges of dry gun-cotton initially exploded by fulminate of mercury, a description of which will be found in Chapter V.

If dry gun-cotton be subjected to a severe blow, an explosion ensues; but repeated experiments have shown that when an explosion is caused by such means as a blow from a hammer, or by the fall of a weight, only the portion actually struck is detonated, the remainder being scattered in an unchanged condition by the force of the explosion.

Gun-cotton can also be exploded by the application of heat, but in this case no report occurs, the explosion being accompanied by brilliant flames and a hissing sound. If the heating is of a gradual nature, decomposition takes place when a temperature of about 60° C. is reached, and acid fumes are given off. As a general rule, explosion does not take place until 130° C. is reached, although it sometimes explodes at a much lower temperature.

Among other properties may be mentioned the fact that gun-cotton is insoluble in ether alcohol, and in its dry state is very hygroscopic, although insoluble in, and unaffected chemically by, water. Compared with gunpowder it explodes more quickly and at a lower temperature, one of its chief advantages being comparative insensibility to shocks. As stated above, there is practically no danger of gun-cotton exploding when in a wet state, and for this reason it is always stored wet, and can be kept in this condition without deterioration for months and even years.

COLLODION-COTTON

In addition to gun-cotton, which is, as already mentioned, the hexanitrate of cellulose, several other varieties of nitrated cotton are known, and under the name of collodion-cotton have been put to a number of different uses. This substance is also an explosive, but is different from gun-cotton in that it is soluble in ether alcohol, whilst the latter is not. It has already been mentioned in Chapter I., that nitro-glycerine being a liquid could not be safely or conveniently used until a satisfactory method of solidifying it was found. With the addition of a small proportion of collodion-cotton, nitro-glycerine forms blasting gelatine, and collodion-cotton also forms an ingredient in a number of other blasting explosives.

It has been found that cotton of a high nitrogen content will give a stiffer gelatine than one of low nitrogen content, but dissolves more slowly. The percentage of nitrogen in collodion-cotton, which is to be used in blasting explosives, is usually somewhere between 11·5 and 12.

The manufacture of collodion-cotton is very similar as regards the main operations to that already described in connection with gun-cotton, but the cotton should not receive drastic treatment with chemicals or heat, as this breaks up the molecules of cellulose and renders the gelatine soft. The nitrated cotton is not boiled for the same reason, but it is treated for several days with water at a temperature just below boiling-point, usually at 90° C., and as a further modification of the gun-cotton process, the pulping is not carried out to the same degree. Blasting gelatine contains about 8 per cent. of collodion-cotton, and one important advantage which this explosive possesses over dynamite, is that the nitro-glycerine cannot be displaced with water, the fact of dynamite possessing an inverse property having led to many accidents.

Another advantage is that the substance added to the nitro-glycerine is itself an explosive, and blasting gelatine is rendered thereby 25 per cent. more efficient than dynamite. It may also be mentioned that among other properties collodion-cotton is soluble in seven to eight parts of ether, to which one part of alcohol has been added, the fluid thus obtained having a syrupy consistency.

Collodion-cotton has attained to a greater importance even than gun-cotton, owing to its diversified employment. It is used in photography, for instance, in the preparation of the exposed plate, in surgery for uniting the edges of wounds, and dissolved in camphor it produces celluloid, the uses of which are too numerous to mention. A solution of collodion-cotton in ether alcohol, to which camphor and castor oil have been added, dries and leaves a film which will not contract, and advantage is taken of this property to coat incandescent mantles to preserve them from breakage during transit.

It will be seen, therefore, that collodion-cotton has a range of use which is greater, perhaps, than that of any other explosive material, whilst as an actual explosive its great usefulness is apparent from the fact that blasting gelatine, for which it is so largely used, has become one of the most successful explosives for shattering hard rock, and is much used in such operations as tunnelling, where it is not necessary to get the rock out in large pieces.

NITRIC ESTERS: (2) NITRO-GLYCERINE

As mentioned in Chapter I., nitro-glycerine was discovered by Sobrero in 1846; it was not, however, put to any practical use until Nobel began its manufacture on a large scale about 1863. Glycerine is a member of the series of organic compounds known as alcohols, and is a by-product in the manufacture of soap by the action of alkalis on oils and fats. It has the chemical formula $C_3H_8O_3$, and the final product of its nitration—that is, the compound which results when nitration is carried to its utmost limit—is called the trinitric-ester of glycerine, an ester being a compound of an organic or inorganic acid and an alcohol. Its earliest uses were confined to the sphere of medicine, being prescribed in very small doses in cases of angina pectoris, but when taken in larger doses it is a strong poison, and merely touching it or inhaling its vapour is sufficient to produce intense headache and sickness in those who are unaccustomed to dealing with it.

Since its discovery nitro-glycerine has been manufactured in a variety of different ways, the safest and most up-to-date being the method now employed at Waltham Abbey, which we shall describe in detail, the older methods being now merely of historic interest.

Pure glycerine must be used, having a specific gravity of not less than 1·26, and this is stored at the factory in horizontal cylindrical tanks built into brickwork and warmed by steam pipes, so as to prevent it freezing in winter, and to reduce its viscosity and thus facilitate its flow. In the same shed which contains the glycerine store tanks are the tanks for storing nitric, sulphuric, and mixed

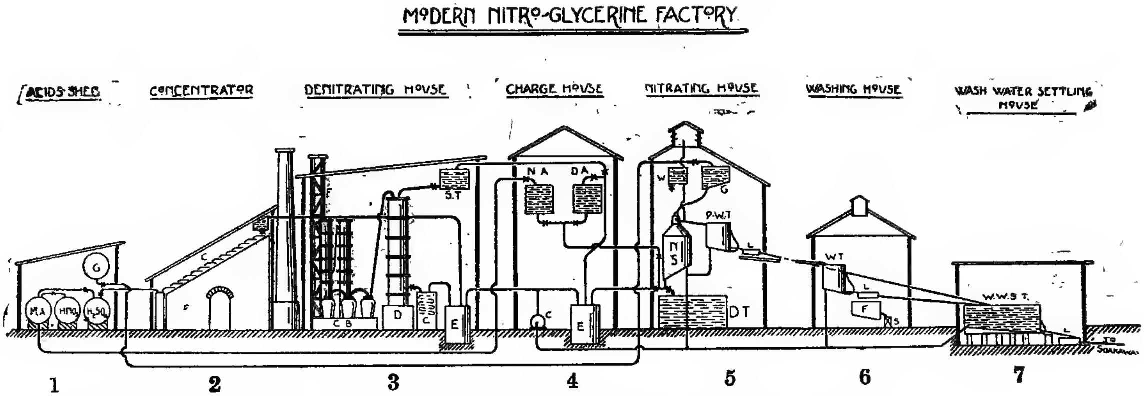


Fig. 10.

1.—*G*, Glycerine store; *MA*, mixed acid store; HNO_3, nitric acid; H_2SO_4, sulphuric acid.
2.—*C*, Cascade; *F*, furnace.
3.—*F*, Fume shaft; *CB*, collecting bottles; *D*, denitrator; *C*, cooler; *E*, acid egg; *ST*, settling tank.
4.—*NA*, Nitrating acids; *DA*, displacing acids; *C*, compressor; *E*, acid egg.
5.—*W*, Water tank; *G*, Glycerine tank; *NS*, nitrator separator; *PWT*, pre-wash tank; *L*, labyrinth; *DT*, drowning tank.
6.—*WT*, Washing tank; *L*, labyrinth; *F*, filter; *S*, soales.
7.—*WWST*, Wash water settling tank; L, labyrinth.

acids, the sulphuric acid being obtained by contract, while the nitric acid is usually made at the factory as described in the section on Gun-cotton. In explaining the conversion of the glycerine into nitro-glycerine in a factory similar to that shown in Fig. 10, which, however, is more or less diagrammatic, it will be convenient to do so under headings which represent the various stages of the process. These stages are as follows:

(*a*) Nitration and separation.
(*b*) Washing and filtering.
(*c*) Recovery and separation of acids.

(*a*) *Nitration and Separation*

The mixed acids for nitrating the glycerine have varied in composition at different times and with different processes of manufacture, but the general practice now is to mix the acids in the proportion of one part of nitric acid to about two parts of sulphuric. The strongest acids are usually employed, that is, fuming nitric and fuming sulphuric, or oleum, which can be more readily reconcentrated, as it is not diluted during nitration to the same extent as ordinary sulphuric acid. The mixed acids are pumped, or lifted by means of compressed air, to the nitrating acids tank contained in the charge house, and are then led to the nitrating house and nitrator separator. The nitrating house is usually a lightly-built structure of wood and corrugated iron, and is surrounded by earth banks 25 to 30 feet thick at the base, and reaching to the height of the roof. It contains a glycerine tank, placed well above the other apparatus, and fed from the glycerine store tank in the acids shed, the nitrator separator, the drowning tank, the pre-wash tank and a shallow trough fitted with baffle plates known as a labyrinth, while there is also a water tank supported at the level of the glycerine tank. The nitrator separator was the invention of Messrs. Nathan-Thomson and Rintoul, of the

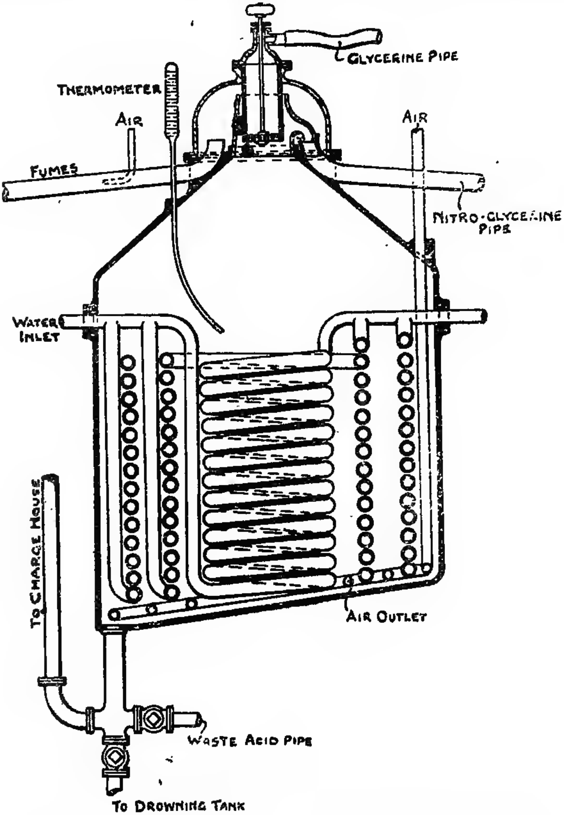


Fig. 11.—Section through Nitrator Separator.

Royal Gunpowder Factory, and a section of the apparatus is shown in Fig. 11. It consists of a cylindrical chamber constructed of lead, having an inclined base and a conical head into which fits a small glass cylinder, open at both ends, and provided with an overflow pipe for carrying off the separated nitro-glycerine. The vessel is cooled internally by means of lead coils in which water—refrigerated if necessary—circulates, while an air pipe is carried down to the base and provided with blow-holes, from which jets of compressed air issue for the purpose of agitating the contents of the vessel. A thermometer is fixed in the conical head and dips well into the nitrating mixture, thus enabling the temperature to be constantly under observation during the whole process, while over the glass cylinder a dome is fitted, which has a central aperture for the reception of the glycerine injector, and is also fitted with a pipe for carrying off fumes.

At the lowest part of the inclined base the entrance pipe for the nitrating and displacing acids is situated. This pipe is provided with three branches, which are taken respectively to the drowning tank, the waste acid egg in the charge house, and the nitrating acids tank, which is also situated in the latter building, while the displacing acids tank is connected to the pipe running from the tank containing the nitrating acids.

The nitrating acids are run into the nitrator by opening the requisite cocks, and are cooled by means of the water circulating in the coils. The quantity of the acids admitted is eight times as much by weight as the charge of glycerine to be nitrated, an average charge being 4,000 lbs. of mixed acids and 500 lbs. of glycerine.

When the acids have been run in and cooled to 16° C., the valve of the glycerine injector, which has previously been inserted at the top of the nitrator, and which is connected by a rubber tube with the glycerine tank, is opened, and the glycerine allowed to run slowly into the acids. The compressed air keeps the mixture well agitated and prevents local accumulation of heat, but the temperature must be constantly watched, and if it rises too rapidly the flow of glycerine must be retarded, while in no circumstances must the temperature of the mixture be allowed to exceed 22° C. (71·6° F.). The fume pipe, which is made of glass, should also be watched and the colour of the fumes noted. If red fumes are evolved the flow of glycerine should be stopped until they cease; but if they continue, the cock at the base of the nitrator must be opened and the contents run into the drowning tank, which is agitated by turning on compressed air. The cock opening connection with the drowning tank is operable from the platform on which the man in charge of the nitrating operation is stationed, and in the event of red fumes appearing it is essential, if a serious explosion is to be avoided, that he should retain his presence of mind and act with promptitude and precision. The temperature at which the nitrating mixture is kept largely influences the time occupied in the operation, which may take from one-half to three-quarters of an hour, and when all the glycerine has been injected the mixture is cooled to 15° C., and the nitroglycerine separates on top of the acids. The cocks admitting the displacing acids are then opened, and waste acids from the previous nitration are run in from the store tank in the charge house. The contents of the nitrator separator are thus gradually raised until the level of the overflow pipe is reached, when the nitro-glycerine runs off and along an inclined trough into the pre-wash tank.

There is a distinct line of demarcation between the nitro-glycerine and the acids, and when this is observed through the windows in the dome to be nearing the overflow pipe, the displacing acids are cut off. The further production of nitro-glycerine during separation is prevented by adding from 2 to 5 per cent. of water to the displacing acids, and this also prevents the mixing of the nitro-glycerine with the acids, and thus obviates the necessity for an after-separating house. The yield from 100 parts of glycerine is about 220 parts of nitro-glycerine, but the output to some extent depends upon the temperature at which the nitration is carried out, and it may be noted that nitro-glycerine is less soluble in the acids when the temperature is reduced. The nitro-glycerine is allowed to flow by gravity to the washing house, as it is too sensitive to be subjected to pumping.

(*b*) *Washing and Filtering*

If hard water is used for washing nitro-glycerine, a hard deposit of calcium carbonate forms on the sides of the washing vessels, and this might very probably be the means of causing serious accidents, and for this reason the wash water is softened before use by treatment with lime or other suitable means. It has been found by experiment that the nitro-glycerine separates much more quickly when the depth of liquid is reduced, and washing vessels are, in consequence of this, made wide and shallow. They are constructed of lead, and their bases slope downwards to one side, where the wash-water and nitro-glycerine exit pipes are situated, while an air pipe passes down the side and is distributed round the base, this being provided for the purpose of agitating and cooling the contents of the vessel. Inside the wash tank is a skimmer, which consists of a rubber tube provided with a handle of the same material, and connected to an outlet pipe and thence to the labyrinth. There is also a rubber tube connected to the lowest part of the vessel for running off the nitro-glycerine, and during washing this is looped up as shown in Fig. 12, and attached to a hollow clip on the side of the tank through which air may be passed. It will thus be seen that all cocks are dispensed with in the flow of the nitro-glycerine, and a constant source of danger and possible explosion is thereby removed. The nitro-glycerine is usually washed four times in the pre-wash tank, the first three washings being done with plain water and the fourth

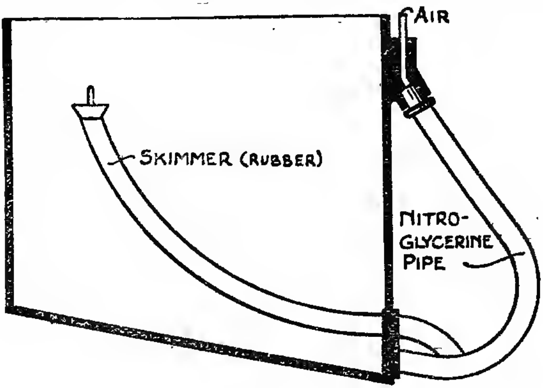


FIG. 12.—WASHING TANK.

with soda solution, the temperature being kept at 18° C. After the nitro-glycerine has separated at the bottom of the tank, the skimmer is gradually lowered, and the wash water runs off and is taken through a labyrinth, which consists of a shallow trough having baffle plates arranged so that the water has to pass over one and under the next, while the bottom of the trough slopes to a central gutter in which any nitro-glycerine carried off with the water settles, and is afterwards drawn off. The wash water, after passing through the labyrinth, is run off to a large wash water settling tank, from which it is again passed through a labyrinth before finally passing to a pond or soak away. When the wash water has been syphoned off from the pre-wash tank, the rubber pipe connected to the nitro-glycerine outlet is unclipped and laid in a trough having an incline of 1 in 1·20 and a length of about 177 feet, and along this the nitro-glycerine flows to the washing house and secondary wash tank. Here it is subjected to five more washings, the first three of which are carried out with water containing 3½ per cent. of carbonate of soda and lasting for fifteen, thirty, and forty-five minutes respectively, while the two final washings are done with softened water only. The temperature is brought to 30° C. at the commencement of each washing, and after cooling and settling has taken place the wash waters are syphoned off as previously described. The amount of water or soda solution used for the washings is about two and a half times more by weight than the quantity of nitro-glycerine to be washed. When the final washing has been effected and the wash water drawn off, passed through a labyrinth and thence to the settling tank, the nitro-glycerine is drawn off through a rubber tube into a lead-lined filtering tank. In the cover of the filtering tank is a cylindrical chamber of wire gauze, having a gutta-percha bottom and a flannel bag filled with salt pressed closely round the wire gauze, and through this the nitro-glycerine filters, the water contained in it being absorbed by the salt and any scum retained by the flannel.

The filter tank has an inclined base, and the nitro-glycerine is drawn off at the lowest part into buckets resting on scales so that the quantity can be weighed; it is then removed to a mixing house, where it is incorporated with other materials, and converted into dynamite, cordite, etc. The wash water settling tank, which is contained in a separate shed, is also provided with an inclined base, and the nitro-glycerine which settles in the tank is periodically removed, the quantity recovered in this way being about 1½ per cent., or only a third of the quantity which had to be removed prior to the introduction of labyrinths.

(c) *Recovery and Separation of Acids*

When all the nitro-glycerine has been displaced from the nitrator separator, the cock beneath the apparatus opening connection with the waste acid egg in the charge house is opened, and the mixed waste acids run off. They are then lifted by means of compressed air to a settling tank contained in the denitrating house, a portion, however, being run through a branch pipe to the displacing acids tank, ready for use for the displacement of the next charge.

The acids, after cooling and settling, are passed to the denitrator, which consists of a tower made of volvic stone and filled with pieces of broken glass and stone, which serve to spread the acids over a large area as they descend. A current of steam and hot air is admitted at the base of the tower, and as it passes upwards and comes into contact with the acids, the nitric acid is separated in the form of vapour, which is condensed and collected in stone bottles and towers and then run off to the nitric acid store tank. The liquid reaching the base of the denitrator, therefore, only consists of dilute sulphuric acid, and this is taken to a cooling vessel and thence to an acid egg, from which it is again lifted to a store tank situated above the concentrator. The sulphuric acid concentrator is usually of the cascade type, and consists of a number of trays and basins arranged on an incline and heated from beneath by furnace gases. As the dilute acid flows down this cascade, the water it contains is vapourized, and the acid, on reaching the bottom, is fully concentrated, and, after being cooled, is run off to the sulphuric acid store tank, to be used again for the mixed nitrating acids. The whole of the waste acids in nitro-glycerine factories have to be denitrated, and any traces of nitro-glycerine which they contain are decomposed during denitration.

Properties of Nitro-glycerine

Nitro-glycerine is an oily liquid slightly yellow in colour, and is clear and heavy, having a specific gravity of 1·6 when pure, its chemical formula being $C_3H_5(ONO_2)_3$. It is very sweet to the taste, but has no smell, and is soluble in ether, alcohol, benzene, and acetone, but only to a very slight extent in water. Moisture, free acid, and sunlight cause its decomposition, although, if quite pure, it is very stable and can be kept for very long periods. Nitro-glycerine solidifies at about

4° C., and in this condition is much less sensitive to shocks, and freezing has been resorted to in order to make its storage and transport safer.

When ignited, nitro-glycerine does not explode, but gives off nitrous fumes, and burns with a yellow flame. In the liquid state it is extremely sensitive to blows, although, as a rule, only the portion actually struck detonates, the remainder being scattered, but it may be readily and completely detonated by means of a fulminate of mercury primer.

NITRIC ESTERS: (3) DYNAMITE

Soon after the introduction of nitro-glycerine as an explosive, laws were passed in several European countries forbidding its use, owing to the disastrous results of its early use in the liquid state. As a consequence of this prohibition, for some years its manufacture was abandoned. Nobel, however, set himself the task of finding a method for rendering the use of nitro-glycerine comparatively safe, and it was not long before his efforts were rewarded with success.

In 1866 he discovered that a fine siliceous earth which is found in Hanover, Scotland, Australia, and Norway, and consists of the remains of very minute animals, had the power of absorbing three times its weight of nitro-glycerine, thus producing a plastic mass convenient to handle and safe to use, which he called dynamite.

The value of this discovery can hardly be overestimated, as not only did it secure for the world the immediate use of a very powerful explosive, but it also gave the initiative to many subsequent attempts to render the practical application of nitro-glycerine sufficiently safe to remove the necessity for its legal prohibition.

Kieselguhr, or guhr, which is the name given to the siliceous earth used by Nobel, is pale red in colour, and contains a certain proportion of organic matter, which has to be destroyed before it can be used for absorbing nitro-glycerine, as, if this was not done, the resulting dynamite would be both unstable and unsafe. This destruction of organic matter as well as the drying of the guhr, which is very hygroscopic, is carried out in ovens, where it is first dried at a high temperature and then calcined at a low red heat.

After calcination, kieselguhr contains over 96 per cent. of silica, together with a small proportion of alumina, iron oxide, and lime, and the prepared material is then intimately mixed with about 10 per cent. of calcium or magnesium carbonate, and sometimes with ochre, the whole mass being then passed through a sieve in order to remove coarse particles of foreign material. After this has been done, the absorbent is weighed out into brass-, lead-, or copper-lined boxes, and nitro-glycerine is poured on, three parts of the latter being used for every part of kieselguhr. The mixture is then allowed to stand for some time until the nitro-glycerine is well absorbed, and it is then kneaded by hand in much the same way as dough. When the kneading is finished, the boxes are transferred to the cartridge huts, outside which are situated storage bins for the finished dynamite.

The cartridge huts are light structures, and should be spaced 40 feet apart and surrounded by thick earth banks, while only a very small quantity of dynamite should be allowed in them at one time, and preferably only two cartridge machines, but in no case more than four.

The cartridge machines usually employed in this country are operable by hand and are very simple in construction, as will be seen on reference to Fig. 13. They consist of a plunger tipped with ivory or lignum vitæ, and working loosely in a pair of guides attached to a wall-bracket, the plunger being provided with a boss from which is suspended, by thin cords, a soft leather conical hopper capable of containing about 1 lb. of dynamite. This hopper fits into the conical mouth of a thin brass tube supported in a bracket immediately beneath the plunger, the end of the latter making a loose fit in the bore of the tube when in operation.

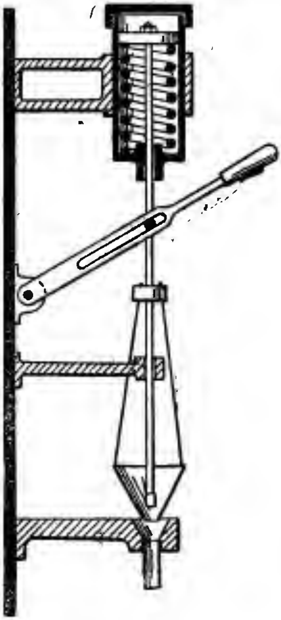


FIG. 13.

The operator first rolls the piece of paper to be used for the cartridge envelope round the exterior of the thin brass tube, the end being then turned over and the envelope slid down almost to the end of the brass tube, and held in position by the operator's left hand. The forked lever operating the plunger is then moved up, the effect of this being to raise the hopper out of the mouth of the tube and thus jerk some of the dynamite into it, while this is compressed into the cartridge envelope on the down stroke of the plunger. This operation is repeated until the required length of cartridge is obtained, when it is removed from the brass tube and the upper end turned over.

The making of these cartridges is a delicate and dangerous operation, and must be performed with great care. The machines should be kept clean and no metallic bodies allowed to lodge in the parts, while the plunger should be kept in alignment with the tube as, should it strike the edge of the conical mouth on its descent, a spark so caused might detonate the whole charge of dynamite. It must be also noted that cartridge making must never be done when the dynamite is frozen—a condition which it assumes at the relatively high temperature of 40° F.—nor should it be attempted when the temperature in the huts falls below 50° F.

The dynamite manufactured in the manner described is known as Dynamite No. 1, and has a buff or brick-red colour, is easily detonated by fulminate of mercury, and burns with a fierce flame if ignited in the open, although it will explode if ignited in sufficiently large quantities. Direct contact with water causes separation of the nitroglycerine, while after long storage free acid is liberated, but it is counteracted by the small percentage of alkali which is added, as described, in the preparation of the kieselguhr.

Dynamite No. 2 is a slower and less powerful explosive, which does not contain more than 18 per cent. of nitro-glycerine, which is absorbed in 72 per cent. of potassium nitrate and 10 per cent. of charcoal. It is, however, very little used at present, and may be distinguished from Dynamite No. 1 by its black colour. Dynamite No. 3 is more powerful than No. 2, and is composed of equal parts of a mixture of wood meal and saltpetre and kieselguhr dynamite.

Kieselguhr, being quite inert, takes no part in the explosion of dynamite and merely acts as an absorbent for the nitro-glycerine, and it was not long after the introduction of kieselguhr dynamite before attempts were made to utilize an active base as the absorbent, and thus increase the explosive power of dynamite. Many different forms of dynamite having active bases have since been placed on the market, and some of these will be briefly described, although a number of them have never been authorized in England. American dynamite, known as Giant Powder, and also Ammonium dynamite, have already been dealt with in Chapter II., under Nitrate Explosives, and therefore need no further description here; but it may be mentioned that the objection to dynamite containing considerable proportions of sodium or ammonium nitrate is its liability to deliquesce—that is, to absorb moisture from the atmosphere, and this it does even in a fairly dry atmosphere, and consequently soon becomes dangerous.

Although millions of tons of dynamite were used in the construction of the great Panama Canal, none of the varieties adopted contained sodium nitrate, an explosive largely used in that undertaking being Atlas Powder, which has the following composition:

	Per Cent.
Nitro-glycerine	61
Wood pulp	14
Potassium nitrate	21
Magnesium oxide	3
Moisture	·2

Atlas powder was also used by the Fenians in their notorious criminal outrages. Dynamite No. 4 is used largely for blowing up earth, and is sometimes called Farmers' or 40 per cent. Dynamite, and contains approximately 40 per cent. of nitroglycerine, ·75 per cent. of nitro-cotton, 16·5 per cent. of dry wood meal and also sodium nitrate.

An explosive very largely used in coal mines is Celtite, which is made up as follows:

	Per Cent.
Nitro-glycerine	56–59
Nitro-cotton	2–3·5
Potassium nitrate	17–21
Wood meal	8–9
Ammonium oxalate	11–13
Moisture	·5–1·5

Carbo-dynamite consists of 90 per cent. of nitroglycerine and 10 per cent. of charcoal, while Trauzl dynamite is somewhat similar, but contains 25 per cent. of nitro-cotton in addition to 75 per cent. of nitro-glycerine and 2 per cent. of charcoal. Rhenish dynamite is composed of 75 per cent. of a solution of nitro-glycerine in naphthalene, together with 23 per cent. of kieselguhr and 2 per cent. of chalk or barium sulphate, and gelatine dynamite is a solution of 6 per cent. of nitro-cotton in 71 per cent. of nitro-glycerine, to which is added 5 per cent. of wood pulp and 18 per cent. of potassium nitrate.

HERCULES POWDERS are also well-known explosives, and their ingredients are mixed in the following proportions:

	Per Cent.
Nitro-glycerine	75–4
Potassium chlorate	1–3·34
Potassium nitrate	2–31
Sugar	1–15·6
Magnesium carbonate	20·8–10

the latter ingredient being added in order to increase the stability.

It is very important that explosives such as the foregoing should be carefully proportioned and made, so as to prevent the formation of carbon monoxide on explosion, instead of the dioxide, the poisonous nature of the former gas making it especially dangerous in mines.

NITRIC ESTERS: (4) BLASTING GELATINE

The credit for the discovery of gelatinized explosives is again due to Nobel, who was the first to find that nitro-glycerine had the power of dissolving collodion-cotton, and thus producing a gelatinous solid which, besides being safer than dynamite, was also much more powerful and convenient.

In manufacturing blasting gelatine the collodion-cotton is first dried, and after being very finely divided is weighed out into brass-lined boxes and the necessary quantity of nitro-glycerine is then poured on, as in the case of dynamite. The mixture is incorporated by hand kneading, and allowed to stand for some time; it is then transferred to a mixing house, where it is heated and gently mixed at a temperature of 50° C., all the nitro-cotton being completely dissolved in about an hour.

The gelatine, which is contained in a trough having a hot-water jacket, is then placed underneath a pair of stirrers, constructed very much like the wheels of a gear-pump on a large scale, and driven from above, and these complete the final incorporation, the gelatine being heated to 50° C. by the circulation of water during the process, and afterwards allowed to stand in order to cool and stiffen. It is then made into cartridges of any required size, in a machine very much resembling the well-known sausage machine, and being almost unaffected by water, these are put into perforated boxes and stored in water tanks. Blasting gelatine continues to harden after manufacture, and therefore becomes more difficult to detonate as it becomes old, a primer of dynamite or gunpowder often being required in addition to the ordinary fulminate detonator. Collodion-cotton is seldom of a constant composition, and is difficult to manufacture so that it has the proper gelatinizing power, and in order to assist the stabilization of blasting gelatine, 1 to 2 per cent. of magnesium or calcium carbonate is usually added. As much as 12 per cent. of soluble nitro-cellulose may be contained in blasting gelatine, but it has already been stated elsewhere that the usual quantity is 7 to 8 per cent. Blasting Gelatine No. 2 has the same composition as that just described, but, in addition, it contains a nitrate and sometimes a certain percentage of charcoal.

Gelignite is also an important explosive, and has the following composition:

	Per Cent.
Nitro-glycerine	60–61
Nitro-cotton	4–5
Wood pulp	9–7
Potassium nitrate	27

Geloxite is very similar to the above, but also contains 12 to 15 per cent. of ammonium oxalate and 10 per cent. of red ochre, while Stowite is also substantially the same in composition. The addition of ammonium oxalate or nitrate has the effect of reducing the temperature of explosion, and this ingredient is therefore often added to explosives intended for mining purposes.

Cordite is a very important explosive, and has a very large military application. It is composed of 30 per cent. of nitro-glycerine, 65 per cent. of gun-cotton, and 5 per cent. of mineral jelly or vaseline, its composition and density always being constant. It takes its name from the form in which it is manufactured, and it is a smokeless powder, and is used in all types of British ordnance.

After being pulped, the gun-cotton used for its manufacture is very carefully dried until it contains only ½ per cent. of moisture, and is then weighed out into brass-lined wooden boxes and taken to the nitro-glycerine washing house, where the requisite quantity of the latter explosive is poured on to it from gutta-percha buckets. The mixture is then conveyed to the mixing house and pressed through a sieve into barrels. In this state of rough incorporation it is called "Cordite Paste," and this is placed, by means of wooden scoops, into an incorporating machine provided with revolving propeller-like blades, a quantity of acetone being added simultaneously as a solvent.

When the charge of cordite paste (usually 75 lbs. or 150 lbs.) has been put into the machine—an operation which only occupies a few minutes—the cover is shut down and the machine run for three and a half hours, after which it is stopped while the required quantity of vaseline is added, and is then run again for another three and a half hours. The "cordite dough," as it is called after incorporation, is then removed and placed into cylinders and taken to hydraulic presses, where it is forced through a die and thus converted into cords, which are wound on reels and then placed in stoves to dry. In the cord form, cordite is used for time fuses, but for use in small arms and artillery it is cut into flakes or cylinders, the diameters of which are increased in proportion to the calibre of the guns in which it is to be used. Cordite is slightly yellow in colour, is unaffected by damp, and is not very sensitive to shocks such as would be produced by the passage of rifle bullets through it. It is very stable, and when ignited burns fiercely without explosion.

CHAPTER IV

AROMATIC NITRO-EXPLOSIVES

Aromatic compounds are so-called because they frequently possess a fragrant odour. The chief source from which they are derived is coal-tar, and the main characteristic in which they differ from compounds such as cellulose and glycerine is the absence of oxygen in them, and this, as will be shown, is a very important fact. The aromatic compounds are of immense commercial importance, as not only are the highest known explosives obtained from them, but they are also the source from which aniline—the basis of all aniline dyes—is derived, as well as being the chief constituent of numerous germicidal substances. Thus, if the aromatic compounds have brought the means for causing terrible destruction of life and property, yet they have also brought the inestimable boon of antiseptics.

Aromatic nitro-compounds are not nitrates, and it will be well here to explain quite clearly the difference between a nitrate and a nitro-explosive.

Excluding mechanical mixtures of nitrates with other substances, of which gunpowder is an example, a nitrate-explosive, such as gun-cotton (hexanitrate of cellulose) or nitro-glycerine (wrongly so-called, as it is the trinitrate or tri-nitric-ester of glycerol), is one wherein the nitrogen is combined with the carbon by means of oxygen, whereas a nitro-explosive is one in which the nitro-group (NO_2) is combined direct with the carbon, and the latter explosives are, therefore, the more stable because they cannot be decomposed by undergoing hydrolysis with alkalis.

The members of the aromatic series which are of interest to us as being convertible into useful explosives, and which will now be considered in detail, are benzene, toluene, and phenol, or carbolic acid.

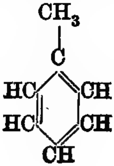
(1) *Trinitrotoluene* (*T.N.T.*)

Trinitrotoluene is one of the most recently developed of high explosives, and is now extensively used for filling shells, having, to a great extent, replaced picric acid for this purpose, owing to its greater stability and insensibility to shock, and to the fact that, being free from acidic properties, it does not attack metals or their oxides, and thus form highly sensitive salts, as is the case with picric acid.

In order to understand some of the technical terms which are constantly met with in connection with trinitrotoluene, and to enable the reader to obtain a clear grasp of the nature of the substance, it will be advisable, before actually describing its manufacture, to explain briefly and as simply as possible the chemical composition and character of toluene itself. When coal-tar, which is a by-product in the manufacture of coal-gas, is distilled by heating it in iron retorts, three separate grades or fractions of oil are produced, and these are collected in separate condensing vessels, and are known respectively as light oil or coal-tar naphtha, middle or carbolic oil, and heavy or creosote oil.

These three portions are each fractionally distilled, the first of them, the coal-tar naphtha, yielding benzene and four other hydro-carbons known as the Benzene Homologues, the first of which is Toluene. This substance is a colourless liquid, having a specific gravity of ·8824 at 0° C., and is, therefore, lighter than water, and boils at 110° C. Toluene is composed of seven atoms of carbon and eight of hydrogen, and, therefore, has the chemical formula C_7H_8; it can, however, be obtained from benzene (C_6H_8) by substituting one methyl-group, which has the formula CH_3 and behaves chemically as a single atom, for one of the hydrogen atoms of the benzene; the resulting compound, which is known as a substitution product, will, therefore, have the formula $C_6H_5CH_3$, which, it will be seen, is identical with toluene, as it contains the same total number both of carbon and hydrogen atoms. Toluene having this formula is sometimes called Methyl-Benzene or Phenyl-Methyl, and it is this substance which is used for the manufacture of trinitrotoluene.

There is, however, another point to notice about the character of toluene and other aromatic hydro-carbons, and that is that their carbon and hydrogen atoms are arranged in a very definite way and linked together in a special manner. This can be readily understood by means of what is known as Kekulé's hexagon formula, and the composition of toluene can, therefore, be expressed thus:



Now it will be noticed that on three sides of the hexagon there are double lines; this means that the carbon and hydrogen atoms are united together in pairs by double links, while each pair is united to its neighbouring pair by a single link, and this arrangement is responsible for the fact that three of the hydrogen atoms are replaceable—that is to say, we can substitute for them three atoms of some other substance such as chlorine or bromine, or three groups of atoms such as the methyl-group (CH_3) or the nitro-group (NO_2) which behave chemically as a single atom under certain conditions, and the full significance of this fact will be readily seen when we come to consider the three stages by which trinitrotoluene is produced.

One other point must be noticed before we leave the consideration of the structure of toluene, and that is with regard to the positions round the hexagon of the replaceable hydrogen atoms. It will be seen that the methyl-group is attached at the top of the hexagon, and this is called position number one, while the other points are numbered clockwise up to six, and the replaceable hydrogen atoms are situated at positions, two, three, and four—one at the end of each single link—while positions five and six are the same as two and three. When a hydrogen atom is replaced by substituting an atom of another univalent substance or a univalent group, a new compound is formed which is given a special prefix, according to which position on the hexagon the new atom or group is attached. Thus, if a nitryl or nitro-group (NO_2) be substituted for the hydrogen atom at position number two in toluene, the new compound formed is called ortho-nitro-toluene; or if the nitro-group be attached

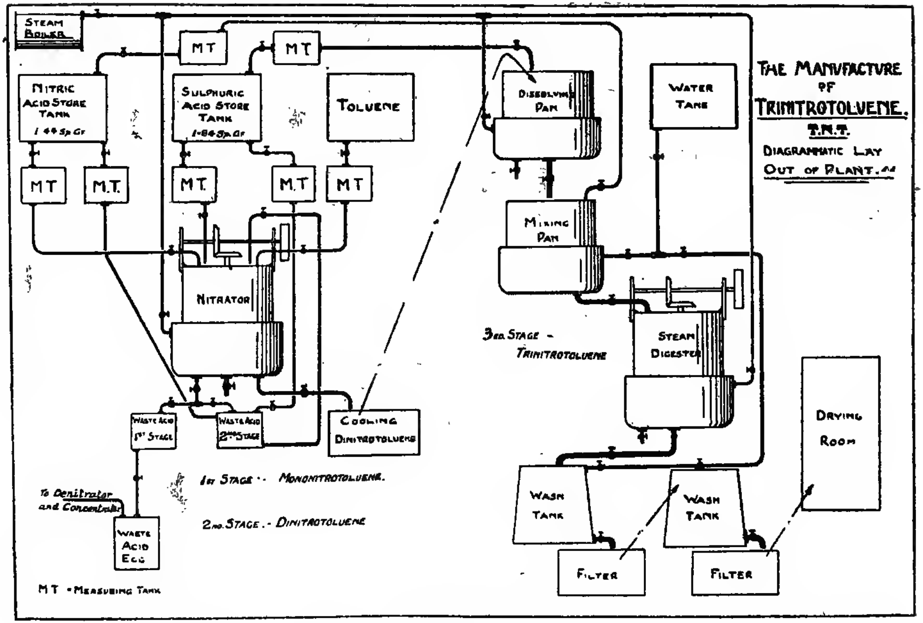
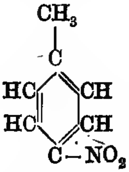

THE MANUFACTURE OF TRINITROTOLUENE. T.N.T.
DIAGRAMMATIC LAY OUT OF PLANT.
STEAM BOILER
NITRIC ACID STORE TANK 1·49 Sp. Gr.
SULPHURIC ACID STORE TANK 1·84 Sp. Gr.
TOLUENE
MT
M.T.
NITRATOR
WASTE ACID 1ST STAGE
WASTE ACID 2ND STAGE
COOLING DINITROTOLUENE
WASTE ACID EGG
To Denitrator and Concentrator
1ST STAGE.. MONONITROTOLUENE.
2ND STAGE.- DINITROTOLUENE
MT - MEASURING TANK
DISSOLVING PAN
MIXING PAN
WATER TANK
STEAM DIGESTER
3RD STAGE - TRINITROTOLUENE
WASH TANK
FILTER
DRYING ROOM

FIG. 14.

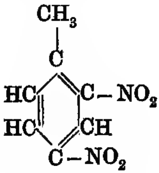
at position number three, it is called meta-nitro-toluene; whilst if it is attached at position number four the new substance is called para-nitro-toluene. These three combinations are the only possible ones, as it will be remembered that positions five and six are the same as two and three, but it is important to remember these prefixes and the positions to which they correspond, as it will be necessary to refer to them again later on. It may also be mentioned here that this formation of substances, having the same chemical formula but with the substituted atom or group attached at different points, is known as "position isomerism."

We are now in a position to understand the stages through which the toluene passes during its conversion into trinitrotoluene, and these will now be described in detail with reference to Fig. 14. By the method we shall first describe, 180 parts, by weight, of pure toluene are passed from the store tank through a measuring tank as shown in the diagram, and thence into a steam-jacketed steel nitrating vat, provided with a central spindle and propeller, driven from a line of shafting by means of a belt and bevel gearing, so as to keep the contents of the vat agitated. When the toluene has been run in a mixture of 315 parts, by weight, of sulphuric acid of 1·84 sp. gr., and 200 parts, by weight, of nitric acid of 1·44 sp. gr., is then admitted into the vat and re-acts with the toluene to produce mono-nitro-toluene by the substitution of a nitro-group (NO_2) for an atom of hydrogen. Moreover, the nitro-group attaches itself in the fourth position, and the new compound is, therefore, termed para-mono-nitro-toluene, and may be expressed by our formula thus:



This, then, is the product of the first stage of manufacture, and as soon as the reaction is complete the waste acids are drawn off and conveyed by suitable pumps, or by compressed air, from an acid egg to a denitrator (see Chapter III.) and re-concentrator, after which the recovered acids are used again.

The mono-nitro-toluene remains in the nitrating vat, and a fresh mixture of acids consisting of 600 parts, by weight, of sulphuric acid and 200 parts, by weight, of nitric acid, are now run in, and the mixture is heated by admitting steam into the jacket, and it is also kept agitated during the operation. This converts the mono-nitro-toluene into di-nitro-toluene by the substitution of a second nitro-group for a second atom of hydrogen. The new nitro-group attaches itself to the second position, and the product is therefore called ortho-para-di-nitro-toluene, the formula for which is:

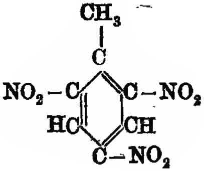


This substance forms an oily layer on the hot acids and is run off to a cooling vessel, while the acids are passed to a waste acid tank where 135 parts, by weight, of fresh nitric acid is added to them in order to revivify them, so that they may be used again in the first stage for making mono-nitro-toluene.

The di-nitro-toluene solidifies after it has cooled to a temperature of 69·5° C. and forms a homogeneous fibro-crystalline mass, pale yellow in colour and fairly hard and brittle.

Another method of preparing di-nitro-toluene, recommended by Haussermann, is by running into a 100 parts of para-nitro-toluene, a mixture of 150 parts of 95–96 per cent. sulphuric acid and 75 parts of 90–92 per cent. nitric acid in the form of a fine stream, while agitating the para-nitro-toluene and keeping the temperature at 60–65° C. The mixture is then heated to 80° C. for half an hour, when all the acid will have been run in, and the contents of the vat are then allowed to stand and cool, when the excess of acid is run off, and the residue crystallizes.

The di-nitro-toluene is now placed in a steam-jacketed dissolving pan, where it is gently heated with four times its weight of 95–96 per cent. sulphuric acid. The dissolved substance is then run into a mixing pan, together with one and a half times its weight of 90–92 per cent. nitric acid, the mixture being kept cool by means of a water-jacket surrounding the mixing pan or by cooling coils placed inside. After mixing in this manner, the substance is run into a steam digester, where it is digested at a temperature of 90–95° C. for between four and five hours, when the evolution of gas will cease, the mixture being stirred at intervals during the process of digestion. The operation is then stopped, the waste acids run off and the residue allowed to cool. It is then washed in dilute soda solution and hot water, after which it solidifies at a temperature of 70° C., forming a white radiating crystalline mass, which is known as ortho-para-tri-nitro-toluene. This substance is the final product of the nitration of toluene, as a third nitro-group has now been substituted for the third replaceable hydrogen atom contained by the latter substance, and this attaches itself to the sixth position, the formula, therefore, being:



or $C_6H_2(NO_2)_3CH_3$.

This is often referred to as 2:4:6 tri-nitro-toluene, owing to the disposition of the nitro-groups.

The melting-point of tri-nitro-toluene is less than that of picric acid, but varies with the purity of the di-nitro-toluene. If, however, tri-nitro-toluene is recrystallized from hot alcohol, crystals which melt at 81·5° C. are obtained. If commercial dinitrotoluene, having a melting-point of 60–64° C., is used for manufacturing trinitrotoluene, the reactions are more violent, necessitating greater precautions being taken, while the yield is less and the consumption of nitric acid 10 per cent. more. One hundred parts of dinitrotoluene should yield a hundred and fifty parts of trinitrotoluene. It is very insensitive to blows, remains stable when exposed to the air for long periods, and is not considered to be explosive during manufacture or storage, although several fatal explosions have occurred at factories where it is made.

It will ignite at 300° C., but will not explode, although, if mixed with caustic potash, explosion may occur at a much lower temperature. Trinitrotoluene is only slightly soluble in hot water, but will dissolve in ether, benzene, and acetone. It also has the power of gelatinizing gun-cotton, and it is used in this way in some explosive mixtures and for making gelatine explosives. Trinitrotoluene is cheaper than picric acid, and is not so poisonous, the dust arising from it being said to have no deleterious effects. It detonates with a No. 3 Detonator containing ·5 gram of fulminate of mercury, but its detonation is not so rapid as that of picric acid, and the force of the explosion is not so great.

The density of trinitrotoluene is about 1·55, and in order to increase this it has been subjected to high pressure; according to one authority the maximum density obtainable with a pressure of about 3,000 atmospheres is 1·7, although, according to Marshall, 1·62 is the limit. Trinitrotoluene is known as Tolite in France and Trilit in Spain, while several other names, such as Trinol and Trotyl, have been given to it. Its applications will be found dealt with in Chapter VI.

Nitro-Benzene

This substance is not very largely used in the manufacture of explosives, although di-nitro-benzene forms a part of several explosive mixtures, being used chiefly as a solvent.

It is manufactured by treating benzene with a mixture of sulphuric and nitric acid, using one part of benzene to two parts of mixed acids. The manufacture is carried out in two stages, the first producing mono-nitro-benzene and the second di-nitro-benzene.

The mixing pan is heated during the second operation, and large quantities of acid and nitrobenzene fumes are given off, which are condensed in suitable apparatus consisting of stoneware bottles and cooling towers, as considerable loss of substance would occur if this were not done.

Nitro-benzene is very extensively used for the manufacture of aniline, which it gives on reduction with hydrochloric acid and iron.

(2) *Trinitrophenol* (*Picric Acid*)

Picric acid has been known for a century and a half, but for a long time it was believed to be a very imperfect explosive unless mixed with other substances, and its chief uses were, therefore, medicinal, and as a dyestuff. It may be obtained by the action of nitric acid on a number of substances, among which are, phenol (carbolic acid), indigo, aniline and resins, but it is also obtained from other substances by means of secret processes. Phenol (C_6H_5OH), which is the substance most commonly used for the manufacture of picric acid, is obtained from the distillate of coal-tar after the removal of the light oil or coal-tar naphtha. It is removed from the distillate by shaking the latter with caustic soda solution in which the phenol dissolves, and is afterwards precipitated by sulphuric acid and fractionally distilled, when it appears as a colourless liquid, which forms a mass of crystals after cooling. Phenol is sometimes called Hydroxybenzene, because it has the same composition as benzene, except that one of the hydrogen atoms contained in the latter substance is replaced by what is called an hydroxyl-group (OH)., that is a group which contains one atom of oxygen and one of hydrogen.

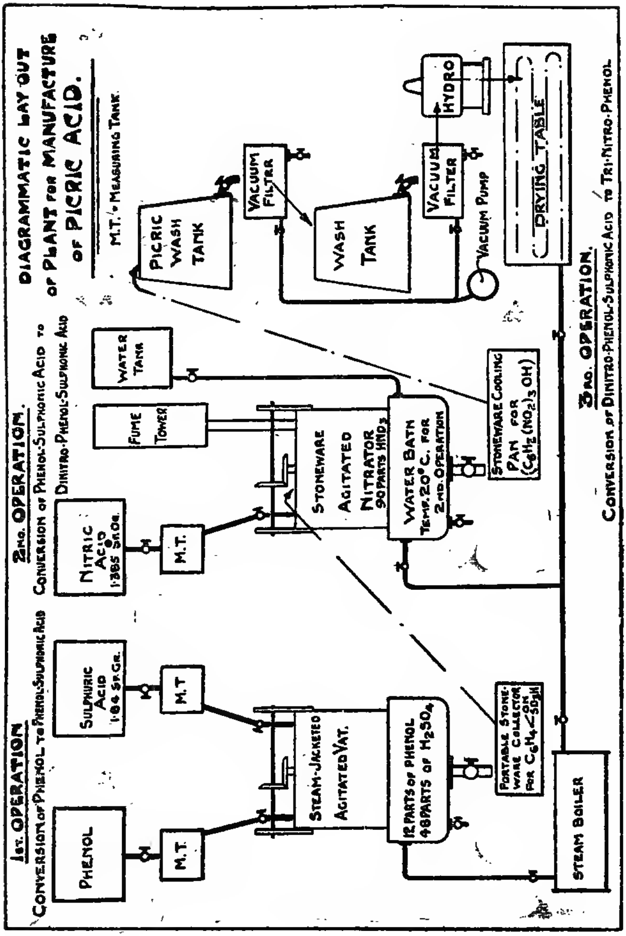
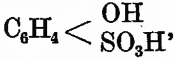

DIAGRAMMATIC LAY OUT OF PLANT FOR MANUFACTURE OF PICRIC ACID.
M.T. = MEASURING TANK.
1ST. OPERATION.
CONVERSION OF PHENOL TO PHENOL-SULPHONIC ACID
PHENOL
M.T.
SULPHURIC ACID 1·84 SP. GR.
M.T
STEAM-JACKETED AGITATED VAT.
12 PARTS OF PHENOL 48 PARTS OF H_2SO_4
PORTABLE STONEWARE COLLECTOR FOR $C_6H_4<^{OH}_{SO_3H}$
STEAM BOILER
2ND. OPERATION.
CONVERSION OF PHENOL-SULPHONIC ACID TO DINITRO-PHENOL-SULPHONIC ACID
NITRIC ACID 1·385 SP. GR.
M.T.
FUME TOWER
WATER TANK
STONEWARE AGITATED NITRATOR 90 PARTS HNO_3
WATER BATH TEMP. 20° C. FOR 2ND. OPERATION
STONEWARE COOLING PAN FOR $(C_6H_2(NO_2)_3OH)$
3RD. OPERATION.
CONVERSION OF DINITRO-PHENOL-SULPHONIC ACID TO TRI-NITRO-PHENOL
PICRIC WASH TANK
VACUUM FILTER
WASH TANK
VACUUM FILTER
VACUUM PUMP
HYDRO
DRYING TABLE

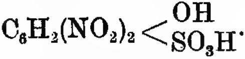
FIG. 15.

Picric acid may be obtained by the direct action of nitric acid on phenol, one part of the latter being added to three parts of fuming nitric acid, the mixture being warmed until the violence of the reaction lessens, when it is boiled until the evolution of nitrous fumes ceases.

The residue is a resinous mass which is then boiled with water, the picric acid which results being converted into sodium picrate by precipitation with sodium carbonate.

Commercially, however, picric acid is manufactured in stages like trinitrotoluene, and the arrangement of the plant for carrying out these processes is shown in the diagram (Fig. 15). The first operation consists in transforming phenol into what is called phenol-sulphonic acid,  $C_6H_4 < \begin{matrix} OH \\ SO_3H \end{matrix}$, and for this purpose sulphuric acid of 1·84 sp. gr. is mixed with phenol in the proportion of four to one in a steam-heated agitated vat, and the mixture is heated for eight hours. The mixture is then drawn off into portable stoneware collecting vessels, where it cools and forms a mass resembling butter in appearance and consistency.

This mass is then placed in small quantities at a time, carried in scoops, into an earthenware, water-cooled pan, containing ninety parts of nitric acid of 1.385 sp. gr. The mixture is kept agitated during the whole of the operation, and the temperature is not allowed to rise above 20° C., the phenol-sulphonic acid being transformed by this process into dinitro-phenol-sulphonic acid,



$$C_6H_2(NO_2)_2 < \begin{matrix} OH \\ SO_3H \end{matrix}.$$

For a quantity of 100 kilograms or about 220 lbs. of phenol-sulphonic acid, the time required for introduction into the nitric acid is twenty hours, and when this is finished and the dinitro-phenolsulphonic acid has been formed, the water contained in the jacket surrounding the nitrating pan is slowly heated by leading in steam, so that during the first four hours of the third operation the temperature of the mixture rises to between 40° and 50° C. The water in the jacket is then boiled, and when the temperature reaches 80° or 90° C. copious nitrous fumes are given off, and these are led through earthenware pipes to absorption towers, where they are cooled and condensed. The water is kept boiling for three or four hours after this violent reaction has ceased, and the contents of the nitrating pan are periodically stirred. The steam is then shut off and the contents of the pan are cooled to 30° to 35° C., when the picric acid will crystallize out. The waste acids are then drawn off and the picric acid is washed several times, and then partially freed of its moisture by placing it in flannel bags in a Hydro-Extractor (Fig. 16) or centrifugal machine which is revolved at a high speed. After being wrung out in this manner, the picric acid contains from 10 to 15 per cent. of water, and it is then passed to the drying rooms for further drying. These rooms must be constructed with the utmost care and attention to detail. The ceiling and walls must be matchboarded or tiled, and the corners should preferably be rounded off instead of angular, while the floor should be asphalted or covered with terrazzo. The drying tables should have their surfaces composed of plate glass, with wire imbedded, and bordered by wooden sides about 9 inches high, and bevelled all round at a sharp angle, so as to prevent any picric acid lodging on them.

The picric acid is spread in an even layer 4 or 5 inches thick over the tables, which are heated by means of steam pipes placed underneath. The rooms must be maintained at a temperature of 50° C., and should be ventilated by means of a fan injecting air through a suitable opening in one of the walls, and the incoming air must be heated by means of a steam coil and freed of its moisture by passing through a cotton-wool filter placed in the inlet opening. The outgoing air should be allowed to leave the rooms by passing through a series of U-tubes containing water, so that while air may pass out of the room, the inrush of cold air is effectually prevented. The lighting of the drying rooms must be effected by means of external electric lamps placed outside the windows of the buildings. During its manufacture picric acid must not be allowed to come into contact with metals or their oxides, as it very readily forms picrates, which are highly sensitive to blows and rapidly detonate.

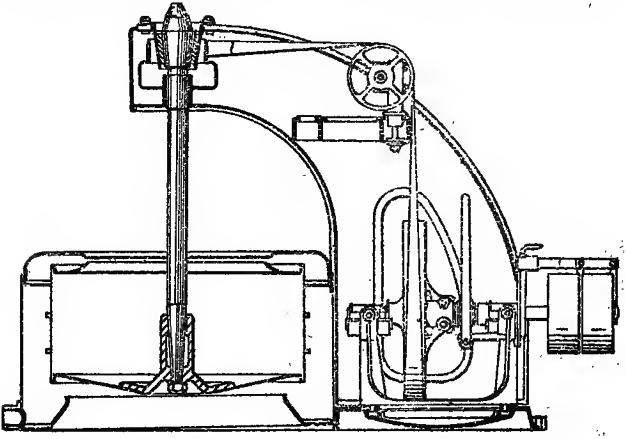


FIG. 16.—HYDRO-EXTRACTOR ("WESTON" TYPE).

On crystallizing, picric acid forms shining yellow prisms, which have an extremely bitter taste and melt at 122·5° C., the chemical formula being $C_6H_2(NO_2)_3OH$, from which it will be seen that, as in the case of toluene, three hydrogen atoms have been replaced by three nitro-groups. Great care must be taken in storing picric acid, and no lime or pieces of plaster and similar bodies must be allowed to come in contact with it, as it may then become liable to explode. Its density, when fused or cast, is about 1·6. Provided, however, that pure materials are used, its manufacture is not dangerous. The yield of picric acid is about 190 parts from 100 parts of phenol, although theoretically this figure should be considerably larger. The discrepancy, however, is accounted for by the oxidation caused by the excess of nitric acid used, which, nevertheless, is necessary in order to ensure the production of the most highly nitrated product. Picric acid only contains about one-half of the oxygen necessary for its complete combustion, and it is, therefore, sometimes used mixed with an oxidizing substance, such as sodium nitrate (Chili saltpetre) or potassium chlorate. There are numerous explosive mixtures which contain picrates as ingredients; the most important of these, however, are Brugère Powder, which contains 54 per cent. of ammonium picrate and 45 per cent. of potassium nitrate, and Designolle's Torpedo Powders, which contain from 50 to 55 per cent. of potassium picrate and from 45 to 50 per cent. of potassium nitrate.

Picric acid is identical with Melinite and Lyddite, and its uses are discussed in Chapter VI.

Trinitro-cresol, $C_7H_4(NO_2)_3OH$, is a substance similar to picric acid, and is sometimes used with the latter substance, notably in France, where it is known as Cresilite.

CHAPTER V

FUSES AND DETONATORS

HAVING followed, in previous chapters, the various steps in the manufacture of explosive substances, we shall now describe briefly the different means which are utilized to cause these substances to explode.

In the early days it was customary to start explosions by applying a light to a train of gunpowder in blasting operations, by the application of a lighted part-fire to the touchhole of a gun, whilst the friction of flint and steel initiated the explosion in a musket; but all these methods were very uncertain and dangerous in their action, and have long since been superseded.

Many attempts have been made to produce a fuse which could be easily and safely transported, and which would burn with regularity in order that an explosion could be accurately timed. Among the various types of fuse, one of the most common is the ordinary safety fuse, in manufacturing which black powder of a fine grain is fed from a hopper into an inverted cone having an outlet at its lower end (Fig. 17). Around the outside of the cone, jute threads, preferably ten in number, are fed, these threads passing through holes in a flange at the upper end of the inverted cone, which is rotated in order that the powder issuing from the lower end thereof passes into a spiral covering of thread. The threads enclosing the powder pass through a hole in a thick metal plate into a tightening tube to compress the fuse, being subsequently wound with thread in another direction, and the whole is covered with tape and waterproofed. This class of fuse, when in use, burns at the rate of 1 foot in thirty seconds.

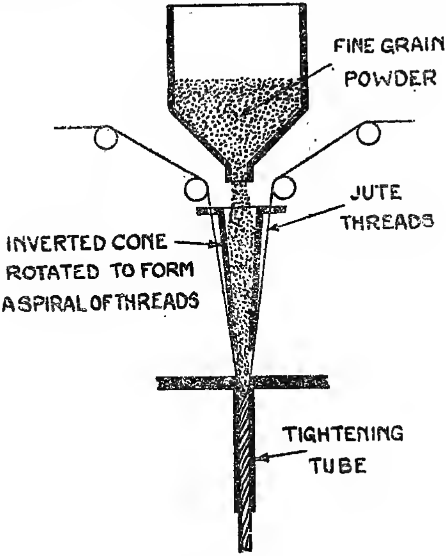


FIG. 17.—DIAGRAM OF MACHINE FOR MAKING SAFETY FUSE.

Fuses which are to be employed in fiery mines have to be more carefully made, and generally consist of a gunpowder core with three coverings of thread, or two coverings of thread and one of tape or gutta-percha. Legislation has been enacted governing the practices in fiery mines, and it is now essential that the fuse should be ignited by means of an igniter contained in a tube which, when attached to the fuse, forms a closed chamber.

MINER'S SQUIB.—This consists of a tapered tube of paper filled with gunpowder, one end of the tube being filled with chemicals to form a slow match. Instead of the paper, quills filled with powder are sometimes used, joined to a slow match. Strips of blasting gelatine are also employed as fuses, but all these devices are dangerous, and can only be used where stringent regulations are not in force.

The *slow match* referred to is made by boiling loose hemp cords in a dilute solution of saltpetre, the resulting product when ignited smouldering away at the rate of 1 foot in several hours.

It has been found, however, that substances can be much more thoroughly exploded by a heavy impact than by mere ignition, the latter often resulting in an undesired slow explosion. To remedy this drawback, what is known as the detonating ignition has been introduced, which consists in applying a strong local explosion instead of a spark or flame.

In connection with nitro-glycerine, this mode of ignition has led to remarkable results. It not only detonates with certainty and without any confinement, but it affords extraordinary facilities for exploding substances which, without its aid, are absolutely inexplosive. As an instance of this, it may be mentioned that if charcoal and saltpetre are mixed without sulphur they do not form an explosive substance within the ordinary meaning of the term, but if a small proportion of nitro-glycerine be added and the whole detonated by a local explosion, the seemingly inert substances will explode with a violence equivalent to that of the nitro-glycerine. Many other instances can be found of non-explosive substances which can be exploded by this means.

The reason for this power which nitro-glycerine possesses of detonating substances which are ordinarily non-explosive, and of "speeding up" slow explosives, can be simply explained. Being a liquid it covers with a fine layer every grain of the substance with which it is mixed, and upon detonation this layer is instantly converted into dense gas at a temperature of 3,000° or 4,000° C. Such a heat must quicken the slowest combustion, and this will no doubt explain the usefulness of explosives which contain inert substances and a small proportion of nitro-glycerine.

It is much more difficult to explain the action of a cap in detonating nitro-glycerine and other explosives. By some it is attributed to the heat produced by compression, some to the heat of the gas given off by the fulminate of mercury in the cap, and others, again, to the dissociating power of vibration, but it is not improbably due to a combination of these three influences.

In practice it has been found to be a great advantage when blasting with charges of ordinary mining powder to detonate them with a primer of dynamite or gun-cotton. The initial detonation causes a much more rapid combustion of the gunpowder, and consequently a more thorough tearing asunder of rocks, than when an ordinary fuse, as above described, is employed.

Detonating Fuses.—With the object of securing a strong initial local explosion, various types of fuse have been devised, one of which is made by filling tubing with picric acid, and subsequently drawing the tubing out to a very small diameter.

In more recent times this has been improved upon by utilizing trinitrotoluene (T.N.T.), which is first melted and then drawn into lead piping under vacuum. When cold, the pipes are drawn out until they are reduced to a diameter of about $\frac{1}{64}$ inch. It is stated that detonators of this class secure great rapidity of explosion.

Fulminate of Mercury, $HgC_2N_2O_2$.—This is one of the best known and most widely used of detonators, being employed in all kinds of blasting work, and in the percussion-caps of shells and bullets.

This substance is chemically a mercury salt of fulminic acid, and is made by dissolving mercury in nitric acid and adding alcohol. The result of the chemical reaction is the formation of heavy white crystals, which are filtered off and dried.

During the process very injurious fumes are produced, which include ethylacetate, acetic acid, ethyl nitrate, nitrous acid, ethyl cyanide, cyanic acid, hydrocyanic acid, and many volatile compounds of the latter, the manner in which the evil effects produced by these fumes may be avoided being described in Chapter VII.

Fulminate of mercury is poisonous, and at every stage of the process of manufacture there is not only the risk entailed by the poisonous fumes, but also the risk of premature explosion. For detonating purposes, fulminate of mercury is often mixed with potassium chlorate and antimony sulphide, and in common with several other substances, which are used as cap compositions and detonators, explodes so easily that it is not allowed to be transported in England.

It is to be noted that many explosives, including picric acid, can only be detonated with fulminate of mercury. For blasting purposes mercury fulminate is enclosed in small, drawn, seamless copper tubes, and detonators of this nature are made in ten different strengths, the sizes and weights being standard in all countries. These detonators vary in length from 16 to 55 millimetres, and in diameter from 5·5 to 7 millimetres, whilst the fulminate charge varies in weight from ·3 to 3 grammes, and in these detonators is not infrequently mixed with potassium chlorate up to 25 per cent.

In addition to the detonating compositions already described, it may be mentioned that picric acid readily forms compounds, called picrates, with various metals, all of which are explosive in nature and are sometimes used as detonators, the most important being those of lead, silver, iron, and copper. They possess the drawback, however, of being very sensitive, and are not allowed to be transported.

CHAPTER VI

APPLICATIONS OF EXPLOSIVES: (1) NAVAL AND MILITARY

MILITARY BLASTING.—For many centuries explosives have played a large part in military operations, irrespective of their use in firearms, being used in sieges for sapping and counter-mining, whilst many instances are on record of city and fortress gates having been blown up by daring soldiers to make a breach for the entrance of attacking armies.

One of the most notable of these exploits was the blowing up of the Cashmere Gate at Delhi, during the Indian Mutiny, by a small party of volunteers, who placed bags of gunpowder against the gate and ignited them by means of lighted matches, several V.C.'s being won in this exploit.

During the investing of besieged cities, the practice of driving a tunnel under the enemy's defences in order to blow the latter up, is frequently resorted to, the explosive medium being generally dynamite or blasting gelatine. Should the besieged obtain knowledge of such proceedings, countermining is resorted to, and not infrequently has led to fierce fights in the darkness of an underground passage. Such are some of the additional horrors that the development of explosives have brought to warfare.

Cartridges of dynamite, or one of its allied substances, are sometimes used with great effect to destroy a bridge or render one span useless and so impede the progress of another body of troops. Other uses of these explosives in warfare are to render fortifications or other buildings useless to an enemy who is likely to occupy them, whilst just prior to the occupation of Antwerp by the German Army in October, 1914, they were deprived of the use of all the shipping in the Scheldt, by the retreating Belgian Army, who were able to quickly and thoroughly blow it all up with modern explosives, while the blowing up of the famous Hill 60 affords another example of the power and use of explosives.

Hand Grenades.—These were commonly used in hand-to-hand fighting during the seventeenth and eighteenth centuries, when the musket was a primitive and rather inaccurate weapon. The grenade gave its name to the Grenadier Guards, and at first simply consisted of a hollow iron ball filled with gunpowder, a lighted fuse being fixed in an aperture in the shell just prior to its being thrown. A lighted grenade forms the badge of many British regiments, including the Fusiliers. At the present day hand grenades have come into general use again after being abandoned for close on a century, but the modern grenades or bombs possess great superiority over the historic ones above referred to, being provided with time fuses ignited by a percussion cap, which is itself detonated by the thrower striking a projection on the bomb against a stone or other hard surface just before throwing. Owing to the danger of bombs exploding prematurely, several types of apparatus for throwing them have been invented. A section of one form of modern hand grenade is shown in Fig. 18.

Mines (Naval).—The value of the mine as a coast defensive agent has been realized and thoroughly developed during the past 100 years, but it was not until electricity was utilized as a detonating agent that anchored mines became of any practical use. At the present day most harbours and river mouths are, in time of war, defended by anchored mines, generally containing gun-cotton, or some form of dynamite or blasting gelatine, which can be operated at any time electrically from shore.

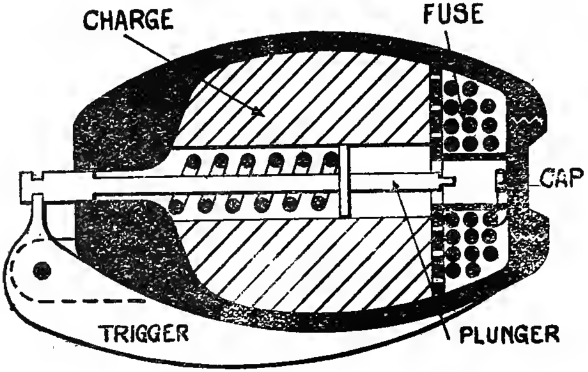


Fig. 18.—Section of Mills' Hand Grenade.

Another form is that known as the contact mine, which should also be anchored, although recently loose floating mines have been sown indiscriminately to the great danger of neutral shipping.

Fig. 19 shows in part section a floating contact mine. Mines of this class usually have a projecting lever which, when struck by a ship, causes actuation of the detonating mechanism, which ignites the primer and, subsequently, the main charge, which frequently consists of 100 lbs. of gun-cotton. To maintain the mine in upright position it is ballasted or anchored as shown. In other forms of floating mines, the breaking of a projecting horn by the impact of any solid body actuates an electric contact-maker, the charge being then ignited by an electric spark.

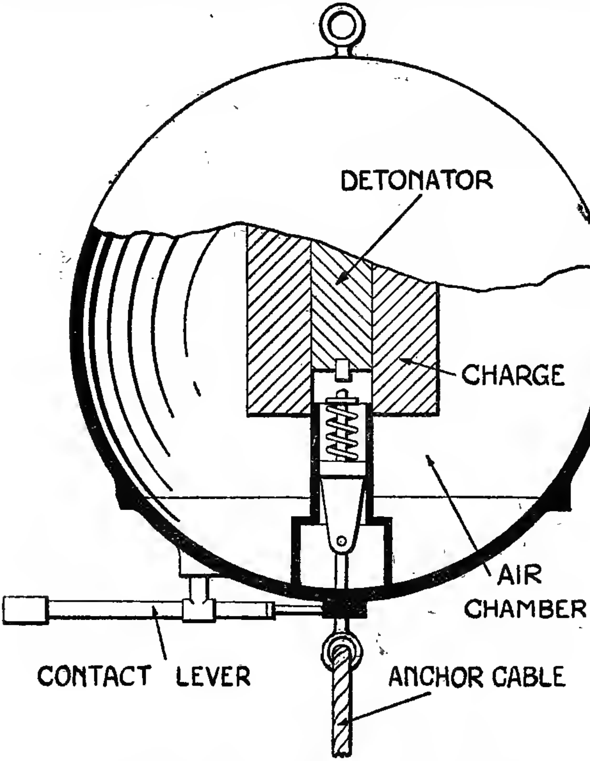


Fig. 19.—Section of Floating Contact Mine.

PROJECTILES.—Gunpowder has now been almost entirely superseded as a propellant for bullets and shells, by some form of smokeless powder, that used in the British services being Cordite. A section of a modern small bore rifle bullet and cartridge is shown in Fig. 20, and the charge used for propelling such a bullet is just over thirty-one grains of cordite made in the form of a thread ·0323 inch in diameter, which is rammed into the cartridge in a special machine. The operation of cartridge-filling is attended with some danger unless the machines are properly cleaned before use, as particles of dust and foreign matter allowed to remain on the ram are quite sufficient to produce enough friction during the operation to cause the detonation of the charge. Cordite is also used for propelling all types of shells, the charge required for a shell fired, say, from a 13·5-inch gun being 187 lbs., this being made up of sticks of cordite 26 inches long and ·44 inch in diameter, tied together in bundles and enclosed in a silk bag before being placed in the cartridge case. In small arms the cordite charge is exploded by means of a percussion fuse, while in big guns it is often detonated by electricity. Cordite is not used for filling the shells themselves, but its invention effectually overcame the diffi-

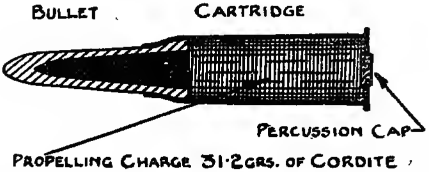


FIG. 20.—SECTION THROUGH MODERN RIFLE BULLET.

culties previously experienced in the employment of gun-cotton as a propellant in artillery.

The earliest explosive shells were simply filled with black powder, the explosion of the propelling charge in the gun being relied upon to ignite the fuse of the shell. This was a very unsatisfactory method, and the shells so fired frequently failed to explode owing to the failure of the fuse to ignite. Shells were then filled with wet gun-cotton as the bursting charge, this being primed by means of dry gun-cotton detonated by a fulminate of mercury percussion fuse or by a time fuse consisting of a cordite train.

M. Turpin, of Paris, discovered that cast picric acid was very suitable for filling shells, as it was quite unaffected by the shock of firing from a gun, but when exploded by a suitable primer and detonator the shell burst with great violence, thus producing very destructive results. Under the name of Lyddite, in England, and Melinite, in France, cast picric acid is largely used at the present time for filling high explosive shells, the molten acid being cast directly into the shell, the interior of which is varnished to prevent the acid reacting with the metal, and which has previously been heated to 100° C., to prevent the picric acid solidifying too rapidly. A conical hole is left in the top of the fused mass for the insertion of a tube containing a primer of powdered picric acid or quick-burning violent gunpowder and a fulminate of mercury detonator.

Quite recently, however, trinitrotoluene has come largely into use as a bursting charge for shells, a section of one filled with this material being shown in Fig. 21. Trinitrotoluene does not affect the metal of the shell, and is very insensitive to shocks, while it is cheaper than picric acid, although not quite so powerful. The body of the shell is filled in the usual manner, about a hundred-weight of trinitrotoluene being used for a 750-lb. projectile,

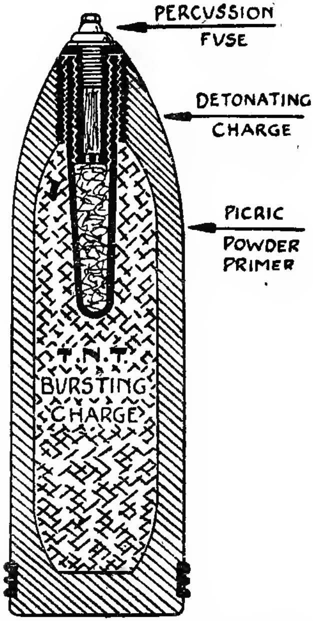


Fig. 21. — Section through Modern High Explosive Shell.

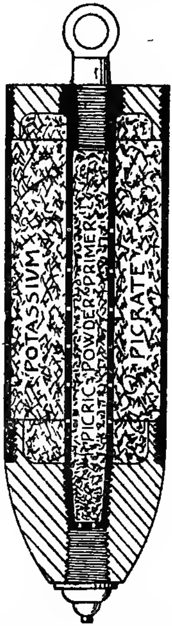


Fig. 22.—Section through Aerial Bomb.

and a space left for the reception of a primer of picric powder, which consists of ammonium picrate and potassium nitrate, which is exploded by means of a detonating charge of cordite or dry gun-cotton, fired by the usual fulminate fuse. It was this type of high explosive shell which, in the early part of the present great European War, wrought such havoc with the so-thought indestructible concrete forts of Liège and elsewhere, while the destruction they are capable of producing in a town subjected to bombardment with them was undreamt of but a few years ago. One has only to visit such a town as Ypres, for instance, in order to witness the wholesale demolition resulting from their use, while the effects of highly explosive bombs, such as have been dropped on London, are too well known to need description here (see Fig. 22). Such, then, are some of the uses of modern explosives, but the ingenuity displayed in their discovery and development was by no means primarily the result of a desire to cause ruin and destruction, for it must be remembered that a great variety of engineering feats have been accomplished by their aid, many of which would have been impossible in pre-explosives days, or would have required the labours of a great many more men and the expenditure of an immense amount of additional time.

APPLICATIONS OF EXPLOSIVES: (2) ENGINEERING

At the time of writing much is being heard of explosives in a military capacity, and the fact of their usefulness in mining, quarrying, and many other engineering operations is apt to be overlooked. As a matter of fact, however, their importance in this direction is such that were the whole world at peace, a large number of persons would still be employed in the manufacture of explosives for blasting, and also sporting purposes.

Explosives have, in many instances, supplanted older and more tedious methods, and we have only to look around at such achievements as the Suez and Panama canals, the Simplon and many other tunnels, to realize the enormous powers that explosives have placed in the hands of man to overcome natural obstacles in the path of rapid transit from one part of the world to another. In addition to these well-known engineering feats it must be remembered that there is hardly a mine or a quarry of importance where explosives are not used to rend and shatter the materials which are being sought.

Passing to other regions of man's activity, we find the harpoon of the whaler is now propelled from a gun, fish can be caught in thousands after the explosion of a dynamite cartridge under water, whilst the rocket apparatus, which has been the means of saving so many lives from shipwreck, is too well known to need further description here.

When and where explosives were first used for blasting, other than in a military sense, will probably never be known, but it is interesting to recall that during the Great Fire of London, which took place in the year 1666, gunpowder was used to destroy a number of houses in various parts of the City to prevent the fire from reaching the Tower. Some years later, when Sir Christopher Wren was engaged in clearing away the ruins of old St. Paul's prior to the erection of the present building, he discovered that fragments of the central tower 200 feet high presented considerable difficulties in the way of speedy removal. Wren determined to try gunpowder, and bored a hole 7 feet deep in the masonry of one of the piers, in which he placed a receptacle containing eighteen pounds of gunpowder. The explosion of this charge raised the pier bodily, and it fell, carrying with it a large part of the ruins. A repetition of the experiment by a subordinate, however, led to some neighbouring houses being damaged, and the further use of gunpowder in the work of demolition was prohibited.

At the present day time is never spent in manual labour when explosives will do the work, and the latter have been successful in operations as varied as blowing up sunken wrecks which are a danger to navigation, in removing wooden piles under water, and in uprooting tree trunks.

As an example of what can be accomplished, the case of the steamer *Chatham* might be mentioned. This ship sank in the Suez Canal in the year 1905, and, as can be well understood, in that confined waterway, it constituted a source of considerable danger to other vessels, and had to be removed. The ship was laden, among other things, with 100 tons of dynamite, and divers went down and placed detonators in close proximity to the explosive, the detonators being connected by electric wires to a point on shore some distance away. The explosion was the greatest ever recorded in connection with dynamite, and caused a jet of water to rise 1,500 feet into the air. The canal overflowed for 1,000 yards on either side, and subsequently a hole 73 feet deep was found to have been made in the canal bed by the explosion.

Dynamite is an important and widely-used blasting agent, and for this purpose it is made up into cylindrical cartridges from $\frac{3}{4}$ inch to 2 inches in diameter, and from 5 inches to 8 inches in length. Of course the manner in which dynamite and other nitro-glycerine mixtures are detonated varies considerably, according to circumstances and the nature of the material which is to be blasted, but, generally speaking, a hole is bored in the mass which is to be shattered of a diameter sufficient to closely fit the cartridge, the latter being cut into several pieces and inserted therein as shown in Fig. 23, with the aid of a rammer, which must be of wood.

The piece of cartridge nearest the outer end of the hole contains one end of the fuse, and is known as the primer. A hole is bored partially through the primer and the fuse inserted, having at its end a cap containing fulminate of mercury, and to hold this cap in place within the primer, the paper of the cartridge is drawn around the fuse and tied tightly with string. This manner of constructing a primer will be more readily understood by reference to Fig. 24.

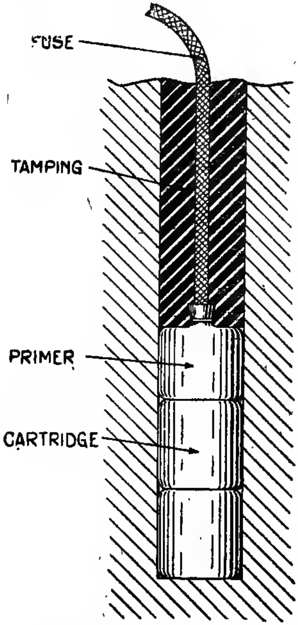


Fig. 23.—Blasting Charge Ready for Firing.

The space around the fuse between the primer and the mouth of the hole is filled with tamping, which, in deep places, may sometimes be water, but which consists in most instances of sand, brick-dust, or clay. Lighting of the fuse explodes the charge, sufficient length of fuse being left to give the operator time to reach a place of safety.

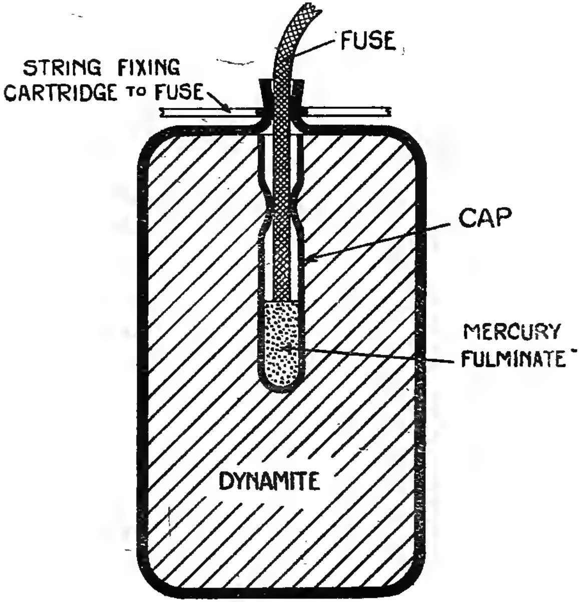


FIG. 24.—PRIMER.

Of late years electric fuses have come into very general use, being much safer to handle and more convenient to use, as they possess the advantage that they can be operated from a great distance if necessary. Fig. 25 shows a platinum fuse which is now used. It consists of a copper shell containing fulminate of mercury and closed at one end by sulphur cement, which also serves to retain a pair of leading in wires in correct position. Within the cap these wires are connected by a small platinum bridge which is heated to redness or combustion by the passage of an electric current, to fire the easily detonating fulminate of mercury and cause the main explosion to take place.

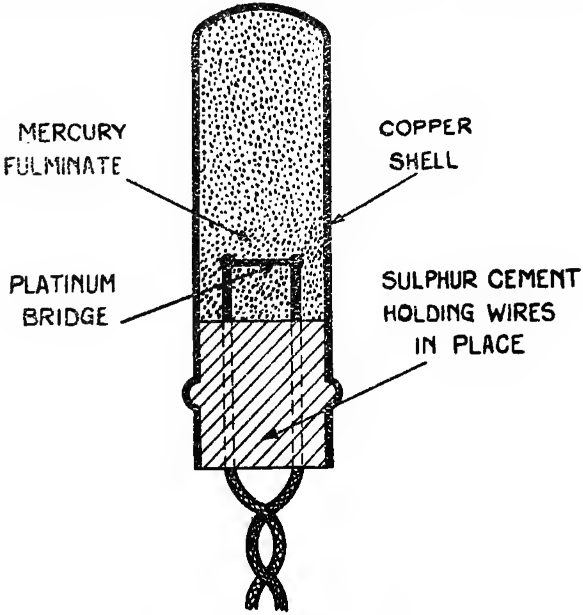


Fig. 25.—Electric Fuse.

The explosives now commonly used in blasting include, besides dynamite, blasting gelatine, rack-a-rock, and gelignite, the means employed to detonate all of these substances being similar to those above described. All of these explosives belong to the class which can be converted into gases with sufficient rapidity to produce a shattering effect on the object confining them, and, as an example of what can be accomplished by their use, it may be of interest to examine briefly a large blasting operation which was carried out some time ago at Genoa in Italy.

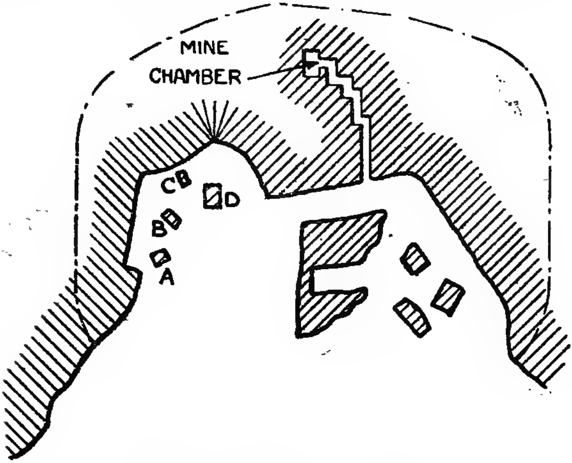


Fig. 26.—Rock Blast at Genoa.

A rocky hillock situated near the river basin of Genoa harbour had been considerably undermined by quarrying until the four pillars A, B, C, and D, Fig. 26, were so weak as to be hardly able to bear the weight of the mass of rock above them which is shown in section in Fig. 27. At about 90 feet from the ground level a zig-zag horizontal tunnel was driven into the rock as indicated, terminating in a well 26 feet deep and 3 feet in diameter, but enlarged at the bottom to form a mine chamber. This was filled with about 5 tons of dynamite, two primers were inserted and sacks of sand piled on top. At every turn of the zig-zag a barricade was erected, and at the tunnel end pieces of timber were piled up and coated with cement so as to ensure the complete confinement of the explosive.

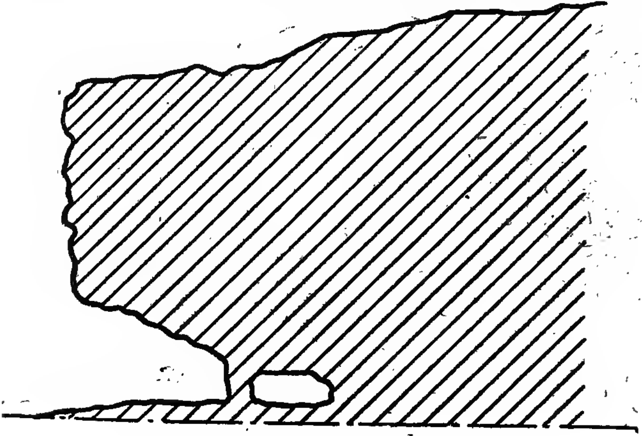


FIG. 27.—ROCK BLAST AT GENOA.

The firing of the mine resulted in the complete breaking up of the hill side within the dotted line, Fig. 26, and the amount of rock loosened is estimated at 480,000 cubic yards.

The nitro-glycerine explosives, however, cannot be always used with safety in mines, whilst in so-called 'fiery' mines they constitute such a source of danger, owing to the presence of fire damp and coal dust, that they are never used. To meet the need thus created, many safety or flameless explosives, such as Roburite, Bellite, Securite, and

Celtite, have been invented, the composition and mode of manufacture of these being described in Chapter II. The method employed to detonate these explosives is nearly always electrical.

The nitro-glycerine explosives, however, give such good results that they are often made up in waterproof cartridges, so that when used in mines they can be detonated whilst completely surrounded by water, which effectually prevents the flame caused by the explosion from spreading and igniting the fire damp. The quantity of water used should be at least four times the volume of the charge employed, or otherwise the flame will not be adequately quenched. Trench's fire extinguishing compound is also stated to have been successfully used as a tamping to prevent the exit of flame from a bore hole.

In very dangerous mines an ancient practice is sometimes resorted to for shattering coal seams without using explosives at all. This method is stated to have been the one employed by the Egyptians in quarrying the large blocks of stone used in their temples and pyramids, and consists in driving wooden wedges into bore holes and soaking them with water until their continued swelling forces the masses of material apart.

This method has been superseded, however, by the use of lime cartridges, advantage being taken of the considerable increase in volume which quicklime rapidly undergoes during the slaking process with water. The safety of such cartridges is shown by the fact that the temperature developed in the interior of the cartridge does not exceed 600° F., and is, therefore, insufficient to inflame a mixture of gas and air.

Lime cartridges have been successfully employed in various collieries, and in use a number of holes are charged at once, the joint action of all the cartridges bringing the coal down in from ten to forty minutes. Provided the charge is properly enclosed, the pressure of the steam generated by the slaking of the lime will supplement the expanding action of the latter in an important manner.

CHAPTER VII

INDUSTRIAL POISONING AMONG EXPLOSIVES WORKERS AND ITS PREVENTION

The manufacture of explosives in this country gives employment to thousands of workers annually, irrespective of the fact of war or peace, and is, therefore, from an economic and industrial, as well as from a military or engineering, point of view an industry of very considerable importance. For this reason then, and also because his personal welfare is a matter of vital importance to the worker himself, a manual of this kind would be incomplete without a consideration of the effects upon the human body and its constitution, which may be produced by the handling of, or the fumes given off by, explosive substances during the course of their manufacture, and which constitute some of the various forms of industrial poisoning.

We purpose, therefore, to devote this chapter to the indication of the ways in which poisoning in explosives factories may arise, the symptoms by which it may be recognized, and the general lines of treatment to be followed in rendering first aid where this may be required, as well as to the enumeration of some simple precautions which should be adopted in order to minimize the risks of poisoning.

There are three ways in which explosive substances or their fumes may enter the human system —that is, by ingestion (swallowing), by absorption through the skin, and by inhalation, the latter being by far the most frequent mode of entry. In nearly all explosives factories nitrous fumes are abundantly present, and, when inhaled, are of a very choking and irritating nature. Workmen should never remain in the nitrating house, for instance, of a gun-cotton factory, during the whole of the process, as, in spite of means adopted, and theoretically supposed to prevent acid fumes rising from the pans, they are, in actual practice, usually much in evidence, and the nitration house atmosphere, therefore, becomes anything but conducive to good health.

Very injurious fumes, containing cyanogen and acetic acid compounds, are given off during the reaction in the manufacture of fulminate of mercury, and these, if inhaled in large quantities, are capable of causing rapid death, while, unless reasonable precautions are taken during the making and handling of fulminate, mercurial poisoning may very often result, one of the evidences of which is the grooving and pitting (erosion) of the teeth, which occurs under the prolonged influence of mercury, the front, or incisor, teeth being usually most affected. Careful attention to the details of personal hygiene will go a long way towards preventing these undesirable effects.

Nitro-glycerine is peculiarly liable to produce injurious effects by absorption through the skin. A single drop of this substance rubbed into the skin after the manner of an inunction has been known to produce serious symptoms, while, if introduced into the body by the mouth, with food for example, and absorbed into the blood stream from the intestinal tract, its effect is very much the same as that of strychnine. The symptoms produced are vertigo (giddiness), weakness of sight, pains in the region of the heart, and stupor, but it is especially liable to attack the nervous system, producing, first, nervous excitement, followed by depression and sometimes central paralysis, owing to its effect upon the spinal cord, while, if more than ten grains have been swallowed, death results. Usually, however, those engaged in the manufacture of nitroglycerine become acclimatized to the substance, and are consequently largely immune from its deleterious effects.

The manufacture of the aromatic nitro-compounds, especially those containing chlorine and toluene, gives rise to fumes which are very irritating to the delicate lining membrane of the respiratory passages and lungs, while benzene fumes are also very overpowering.

In the year 1905 over 50 per cent. of the workers in factories manufacturing aromatic nitro-compounds suffered from anæmia and cyanosis (a bluish-grey appearance of the skin due to imperfectly oxygenated blood), and this in spite of frequent medical examination. One man given hospital treatment for cyanosis, difficulty in breathing, and general weakness, had not been employed in the factory for more than ten days. In one badly ventilated factory every employee suffered either from anæmia, cyanosis or tremor. Nitro-benzene poisoning is very common in Roburite factories, and sometimes causes optic neuritis, while many cases of poisoning by this and similar substances are caused by the careless splashing of the liquid on the clothes.

Great care should be exercised in handling dinitrophenol, as the fumes arising from the moist substance may cause complete collapse, accompanied by heart pains, vomiting fever, rapid pulse and convulsions, and followed, in some cases, by death. Ammonium compounds also give off injurious fumes in the course of their manufacture.

Abstinence from alcohol in every form is especially desirable in explosives workers, and, at all events, most certainly during working hours. This is a point of the utmost importance, and no apology need, therefore, be offered for insisting upon it, as it must be remembered that the aromatic nitro-compounds as well as nitro-glycerine and allied explosives are soluble in alcohol, and its presence in the system, therefore, renders the absorption of the fumes, or substances themselves, into the body far more certain and easy. As an example of this it may be mentioned that some years ago several chlorbenzene workers were discovered unconscious in the street after heavy drinking, and only recovered consciousness some twelve hours after admission to hospital. It will be obvious from the foregoing remarks, that alcohol should never be administered to a patient suffering from the presence internally of nitro-benzol or similar substances, under the mistaken idea of strengthening and stimulating him, nor, indeed, should it be given in any case of poisoning due to the fumes of explosive compounds, but, as substitutes for alcohol, tea, coffee, and milk, and especially the latter, are excellent for explosives workers. Men who are not used to working with chlorbenzene frequently show signs of poisoning after quite a short time, their symptoms being headache, cyanosis, distress in breathing, and fainting attacks, while similar effects are produced in nitro-toluene factories and are the result, partly, of nitrous fumes and partly of those of nitro-toluene.

Picric acid is a strong local irritant, and besides producing skin affections, also irritates the respiratory passages and causes gastric and intestinal catarrh and inflammation of the kidneys when its dust is inhaled, while, in some cases, it may produce a rash resembling that of measles or scarlet fever, and usually produces a jaundice-like discoloration of the skin, while considerable prostration sometimes occurs among those engaged in packing it. Picric acid has a very bitter taste, and its fumes, when it is in a molten condition, are very poisonous. Trinitrotoluene dust is said to be non-injurious.

Aromatic nitro-compounds and also nitro-glycerine and the fumes produced in their manufacture, have a very definite action upon the blood, in that they combine with its red colouring matter (hæmoglobin), and form what is known as methæmoglobin, which has a characteristic chocolate colour.

The oxygen of the blood is so firmly combined in the methæmoglobin, that the interchange of gases which normally takes place in the lungs, where the blood is regenerated, and which is so essential to life and health, is rendered more or less impossible, and it is this fact which explains the rapidity with which death is sometimes produced after the inhalation of large quantities of benzene and similar fumes.

The symptoms of explosives poisoning are very similar in the case of all the various compounds, and may be summarized in the order in which they usually occur, as follows: Cyanosis, or blueness of the skin (especially the face, lips, and nose, and pallor of the mucous membranes, as, for instance of the mouth), headache, nausea, and anxiety, difficulty in breathing and walking, and impairment of sight, chest pains, vertigo (giddiness), vomiting, sleepiness, stupor, and finally death, while dilatation of the pupils of the eyes may also be present.

It will be noticed that the discoloration of the skin appears first, and this is, in fact, always the premonitory symptom, and usually appears before the patient actually complains of feeling ill. When this is observed by a fellow-worker, he should take immediate steps to remove the affected man from the vicinity of the fumes into the open air, while, if difficulty in breathing is experienced and the cyanosis is considerable, oxygen (which should always be kept at the factory in case of emergencies) must be at once administered, or artificial respiration resorted to, the administration of oxygen, however, being of primary importance. If the poisonous substance has been swallowed, as, for instance, through eating food with improperly-washed hands, an emetic, such as mustard or salt and water, or a teaspoonful of lead sulphate in a tumblerful of water, should be given, while, if these fail, tickling the back of the throat with the end of a feather will usually produce the desired result, but, in either case, medical assistance should be obtained as soon as possible.

There are numerous ways and means which may be adopted with the object of preventing and minimizing industrial poisoning in explosives factories, but their employment, or, at all events, their success, must depend upon one fundamental condition—namely, the interest and intelligent co-operation of the workers themselves. All the rules and instructions in the world will be unavailing in the prevention of untoward effects, unless the worker realizes that they are formulated for his protection, and is, therefore, prepared to carry them into practice. That familiarity breeds contempt is equally true of explosives workers as of any other class of people, and it is essential, therefore, that they should understand the nature and properties of the substances with which they have to deal, in order that they may realize the danger and folly of relaxing their observance of the few simple precautions which are necessary for the maintenance of their normal health. Education by means of lectures, leaflets, or notices hung in workrooms, explaining the physical and chemical properties of the substances manufactured and their physiological effects on the human system, is one of the best and strongest defensive measures which can be adopted. The working hours should be short, or, at any rate, the work should be done in short shifts, and, when possible, the men should be given a periodical change of occupation. Explosives workers should be men of robust health, and should have plenty of good nourishing food, as underfed workers are much more liable to be speedily affected by injurious fumes and dust. They should also be men of temperate habits, as industrial poisoning is far more dangerous to life and health when complicated by alcoholism. Periodical medical examination is carried out in many explosives factories, and is of considerable importance and practical value, as the early stages of poisoning may then be recognized and the affected workers temporarily removed from their deleterious surroundings.

All workrooms should be lofty and spacious, well ventilated, and as cool as possible, the latter being an important point, as a low temperature in the rooms of explosives factories is always coincident with a low percentage of sickness; while the floors should be composed of asphalte, or some similar material which is easily cleansed and freed from dust, the junctions of the floor and ceiling with the walls being rounded off instead of angular so as to prevent the possibility of the lodgment of dust, especially in picric acid factories in the drying and packing rooms. Suitable washing accommodation should be provided for the workers, and also cloakrooms, where the ordinary clothes should be changed for working clothes, which should be made of impermeable material, with as few folds and pockets as possible. Merely putting overalls over ordinary clothes is not sufficient to properly safeguard the well-being of the worker, but he must be careful to change his working for his ordinary clothes before his mid-day meal, and also to thoroughly wash his hands, the most efficient method of doing this being by means of mechanical friction with soap and a stiff nail-brush. It is, of course, most important that no food should be taken into the workrooms, but a proper messroom, where meals could be obtained at a reasonable price, or food brought in could be left until meal-time, should be provided. When it is necessary for men to handle explosive substances, such as nitro-glycerine, dynamite, picric acid, and the like, suitable gloves should be worn, and the substance allowed to come in contact with the skin as little as possible.

Workers should never remain in a room where nitric acid has been spilt, especially if it has come in contact with organic matter, and all fumes evolved during nitration processes and the denitration of waste acids should be carried away by exhaust fans and properly condensed, while packing and other rooms where dust is present should be provided with air purifiers and dust traps, Fig. 28. If proper health is to be maintained, exercise must not be neglected, and warm baths should be frequently indulged in, but provided the precautions suggested in the preceding remarks are carried into effect, there is no reason why the explosives worker should not enjoy an equal measure of health with that of the worker in more arduous but less dangerous occupations.

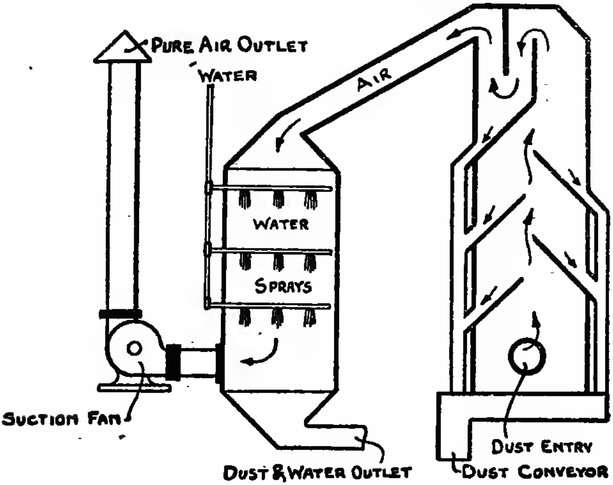


FIG. 28.—DIAGRAM OF AIR PURIFIER AND DUST TRAP.

CHAPTER VIII

LEGISLATION ON EXPLOSIVES

FROM very early times it has been found necessary to effect legislation in order to safeguard life and property in the vicinity of places where explosives are made, and to prevent, as far as possible, any damage being caused by the explosion of highly sensitive substances during transit from one place to another.

Acts of Parliament, however, do not form very enticing reading matter, but it is felt to be desirable that those engaged in manufacturing and handling explosive materials should be able to understand readily what may or may not be done with them. This chapter, although not claimed to be a *précis* of the Explosives Act of 1875, yet contains the principal points of that Act in simple language for the guidance of manufacturers and workpeople who may not be quite clear as to what should be done in respect to licensing and inspecting explosives factories, what to do when an accident occurs, or how to send explosives by road, rail, or ship, and conform to the official regulations.

The word "explosive," as used in the Act, covers every conceivable form of explosive material, and, besides the important explosives, includes fog signals, fireworks, caps, detonators, and all kinds of rifle and artillery ammunition.

The Act divides explosives into two classes—gunpowder and explosives other than gunpowder; but the provisions in the two sections are in general very similar except in regard to quantities that may be stored, etc. The second part also stipulates that two explosives of a different nature may not be stored together, except under certain specified conditions. The reason for this will be obvious, as one explosive may be easily detonated and explode another substance which, if stored alone, would not explode.

Buildings.—These must be licensed by the Home Secretary with the assent of the Local Authority within whose bounds an explosives factory is to be started. A penalty is imposed on anyone who either makes or stores explosives in an unauthorized place.

Licenses are only granted for the manufacture of the explosive specified therein, but the manufacture is permitted of other explosives if on a small scale for experimental purposes only.

The finished explosive can only be stored in specially prepared buildings a specified distance away from the buildings where it is manufactured.

In places where the occupier of a registered store wishes to fill cartridges with powder, a factory license need not be taken out provided that certain specified rules are followed. Not more than 5 lbs. of powder may be in the cartridge-filling room at once, and other work must not be carried on in this room. No fire or artificial light must be present, and the filling room must be detached from the store. These are only reasonable provisions, as can be readily understood when it is remembered what tremendous damage might result from the accidental dropping of a glowing match or the detonation that would follow the fall of any heavy object on some sensitive materials.

All stores in mines and quarries must also be registered, but occupiers of such need not apply for a factory license to prepare explosives for their own use. Here, again, certain conditions conducive to safety are imposed. There must not be in the workshop more than 100 lbs. of gunpowder or a prescribed amount of other explosive. No other work must be carried on in the same workshop, which must be an isolated building, and explosives may not, in these circumstances, be converted from one form to another or resolved into their ingredients.

The Act further states that no unauthorized person may approach or enter an explosive factory.

Inspectors are appointed under the Act in Local and Harbour Authorities, and have extensive powers of search and inquiry in all places where explosives are manufactured, stored, or used, inspection being necessary to see that the above described safety conditions are carried out, and also to ensure that no explosives which are on the official prohibited list are being manufactured or transported.

After an accident which is due in any way to explosives, an official inquiry must be held, and the Local Authority should be immediately notified of any such accident taking place.

Transit.—All explosives must be securely packed in wooden cases, marked with the name of the explosive, and only certain prescribed amounts may be transported in one case, the amount in the case of gunpowder being 100 lbs. Railway and other authorities are empowered to utilize special vans for this purpose, and in the case of explosives coming from abroad importation licenses are necessary.

Sale.—Explosives may not be hawked or in any way exposed for sale in a public place. They may not be sold to children, and when sold must be in a canister or case clearly marked with the name of the explosive.

Local and Harbour Authorities, Railway and Canal Companies are empowered to make any by-laws they may deem necessary for the minute regulation of the explosives traffic, and in the interests of public safety.

The schedule at the end of the British Explosives Act of 1875 previously referred to has been amended several times, in order to bring up to date the list of permitted and prohibited explosives, such amendment being necessary in view of cases of highly dangerous substances like nitro-glycerine being rendered more safe to handle in the form of dynamite.

INDEX

Abel, Sir F., 5
Air-purifiers, 109
Alcoholism and industrial poisoning, 107
American dynamite, 21
Ammonium chlorate, 23
    dynamite, 21
    nitrate, 18, 19
    perchlorate, 24
Antimony sulphide, 24
Aromatic compounds, 62
Atlas powder, 56

Bacon, Roger, 1
Ballistite, 7
Bellite, 17, 98
Blastine, 24
Blasting, 92, 93, 94, 95, 96, 97, 98
    gelatine, 20, 39, 40, 58
    collodion cotton in, 59
    detonation of, 59
    invention of, 6
    No. 2, 59
    storage of, 59
Braconnot, 4
Brugère powder, 77
Bullet, propelling charge for, 88

Carbo-dynamite, 57
Carbonite, 21
Celtite, 57, 99
Charcoal, 8, 9, 10
Cheddite, 23
Chlorbenzene poisoning, 104
Collodion cotton, 24, 39
Concentrating spent acids, 51
Copper picrate, 83
Cordite, 7, 60, 88, 90
Cresilite, 77
Cresol, trinitro-, 77

Denitrating waste acids, 50
Designolle's torpedo powders, 77
Detonating fuses, 81
Detonation, explanation of, 80, 81
Dinitro-benzol, 18
Dinitro-naphthalene, 19
Dynamite and Panama Canal, 56
    applications of, 93, 97, 98
    cartridges, 53, 54, 55
    discovery of, 6, 52
    farmer's, 57
    Nos. 1, 2, 3, and 4, 55, 57
    properties of, 55, 56

E.C. powder, 6, 16
Esters, nitric, 26
Explosion, reduction of temperature of, 59
Explosives Act (1875), 110
    definition of, 1
    entrance of into body, 102
    factories, licensing of, 111, 112
        workrooms in, 107, 108
    for projectiles, 88, 89
    for blasting, 92
    high effects of shells, 91
    nitrate, 15
    nitro-, 62
    poisons, action of, on blood, 105
    poisoning, antidotes for, 106
        prevention of, 106, 107
        symptoms of, 105

Nitro-glycerine, properties of, 51
  separation of, 47
  secondary washings of, 49
  symptoms of poisoning by, 103
  wash tanks for, 47
  yield of, 47

Optic neuritis, 103

Panama Canal, 56, 91
Permonite, 24
Petrofracteur, 24
Phenol, 72
  trinitro-, 72
  -sulphonic acid, 74
    dinitro-, 74
  dinitro-, poisoning by, 104
Picrates, 83, 90
Picric acid, cast, for shells, 89
  drying rooms for, 75, 76
  effects of, on human system, 105
  hydro-extracting, 75
  properties of, 77
  use of as explosive, 6, 89
Picric powder, 90
Position isomerism, 67
Potassium chlorate and perchlorate, 24
Primers, 94, 95

Rack-a-rock, 32
Rendrock, 22
Rhenish dynamite, 57
Roburite, 18, 98

Safety explosives, 98
Saltpetre, 2, 8, 9, 11
Schulz powder, 6, 15
Schwartz, Berchtold, 2
Securite, 17, 98
Shells, 89, 90
Smokeless powder, 6, 60
Sprengel explosives 23
Steelite, 24
Suez Canal, 91 [illegible]
Sulphur, 2, [illegible]

Trench's co[illegible], 18, 99
Toluene, source of supply of, 63
  chemical nature of, 64, 65
  nitro-, symptoms of poisoning by, 104
Tonite, 17, 18
Trauzl dynamite, 57
Trinitroluene, advantage of, 18, 63, 70
  applications of, 89, 90
  manufacture of, 67, 68, 69
  properties of, 70, 71
Turpin, Eugêne, 6, 89

Veille, 6
Vigorite, 22
Vulcan powder, 22

Wren, Sir Christopher, 92
Working clothes, importance of, 108

Xyloidine, 4

Yonckite, 24
Ypres, effects of explosives on, 91

THE END

BILLING & SONS, LTD., PRINTERS, GUILDFORD, ENGLAND.